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CYCLES OF DROUGHT
AND
GOOD SEASONS
IN
SOUTH AFRICA

WITH CYCLICAL DIAGRAMS

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CYCLES OF DROUGHT

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SOUTH AFRICA.

BY

D. E. HUTCHINS,

CONSERVATOR OF FORESTS, KNYSNA.

WITH CYCLICAL DIAGRAMS.

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Pierce

PREFACE.

THIS reprint has been prepared at the request of friends who were unwilling that the interest aroused in a subject of national importance, so far brought together in these two lectures, should perish in the oblivion of newspaper reports. The first lecture was printed *in extenso* in the "Kaffrarian Watchman" and subsequently in the "Grahamstown Journal." The second lecture has not hitherto been published. It has been added to, and in great part re-written, at leisure moments, during the past year, and has thus taken the form of a paper rather than a lecture. The key to the Cape Western climate furnished by the Sunspot cycle and the secondary Storm cycle of rainfall, has been a matter of genuine and pleasurable surprise to me. It is more than a surprise, that this key should have turned out so complete, as to enable one to forecast the character of the seasons, for the next 50 years, sufficiently closely for practical purposes.

For the Eastern rainfall we have neither the long Meteorological records, nor the striking cyclical regularity, that is observable in the Western rainfall. But enough regularity remains to render its cyclical variation of practical importance to almost every one in the Colony. For this reason, I have chosen a popular form of publication and expressed my conclusions in popular language. At the same time, the figures on which these conclusions are founded are added, so as to admit of easy verification. The figures are presented to the reader exactly as they come from the raingauge, avoiding all manipulation or smoothing of irregularities, such as is sometimes neccessary in investigations of this nature. Where the authority is not otherwise stated it will be understood that the figures are extracted from the reports of the Meteorological Commission of the Colony published yearly at Cape Town. To the courtesy of its overworked Secretary Mr. W. Ellerton Fry, I must add my grateful acknowledgements. To the Authorities at the Royal Observatory, I am indebted for permission to consult its library.

In conclusion, I should like to add a word for the Meteorolgical Commission. Is there any branch of the Public Service engaged in a task of such usefulness that is so meagrely supported? I have a purely scientific interest in its labours and can therefore speak disinterestedly. Last year the total sum at the disposal of the Meteorological Commission was £500 0s. 0d. When one asks a farmer. "Will it pay to plough here?" For the great bulk of the land one gets this answer. "It pays in good seasons." It is the work of the Meteorological Commission that now enables us to tell the farmer, with a yearly increasing exactness, when to plough and when to give the land rest. A drought such as that which closed in 1885 brings home the fact that, not only farmers, but tradesmen, merchants, capitalists, and every class of the community, in South Africa, are interested in a foreknowledge of the character of the seasons.

I regret that expense has prevented the reproduction of more of the cyclical diagrams. The Sunspot cycle referred to in these lectures is the 11·11 year cycle of Dr. Rudolf Wolf. In the last lecture will be found developed the precision now attaching to cyclical methods of study, consequent on the discovery of the secondary cycles in the meteorology of the Southern hemisphere.

SUNSPOTS AND SEASONS:

A LECTURE,

DELIVERED

BEFORE THE NATURALISTS' SOCIETY,

KING WILLIAM'S TOWN,

NOVEMBER 1886.

BY

D. E. HUTCHINS,

CONSERVATOR OF FORESTS, KNYSNA.

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SUNSPOTS AND SEASONS.

Few speculative subjects could have a more practical interest for us than that of the influence of sun-spots on the apparently whimsical weather of South Africa. We are accustomed to the storm that smites by day, to the rigours of an arctic cold by night, to the hot wind that kills in its unpitying grasp, to the floods that in a few hours destroy the labour of years. Whence these mighty forces come, we know little, beyond the light of a few physical laws. Of the terribly practical question when these gods of the air will strike us we know less. But above this seeming chaos there may be discerned a small but all pervading influence ; infinitesimally small if we consider it at any one point, but by no means insignificant looking at the immense area over which it acts. This influence is the modification in the sun's power with which we are all more or less familiar under the name of sun-spots.

One sometimes hear people allude to the "sun-spot theory," as if the sun-spots themselves were a matter of theory. I need scarcely tell anyone here to-night that the sun-spots themselves are quite as much a matter of certainty as the existence of the sun. Theory comes in when the influence of the sun-spots on our affairs is discussed. But as regards the sun-spots and the constitution of the sun itself we are on quite firm ground. We know that it is easy to split up the sun's light into heart rays, light rays and dark chemical rays, into the colours of the spectrum—red, orange, yellow, green, blue, indigo and violet. The chemical or actinic rays are mainly concerned in making plants and trees grow. Most of the chemical elements of which our earth is composed exist in the sun, but as might be expected in very different combinations to those with which we are accustomed on the earth. Of the hydrogen and oxygen so common here, the former only shows out abundantly in the sun.

What I should like to carry your attention to for a moment is this—the enormous necessity the sun is to us. Every pulsation of life on the earth, all growing things, men, animals, plants, trees, draw the energy of their life either directly or indirectly from the sun. All the forces we see around us, heat, light, electricity, wind power, water-power, all with one exception are drawn more or less directly from the sun. This one exception is that of the lunar tides. This is all the energy we get from the little moon, near us though it is: so near, in fact, that through a small telescope, it appears as if we could step on to its shores; or follow out Jules Verne's fancy, and send a band of emigrants there. But the moon is really a dead thing, and the sweet beauty of its soft splendour, which few can appreciate better than we in South Africa, is but the far distant reflection of the intense heat and energy glowing in the sun. Perhaps some day a poet may arise and bring home to our feelings what we now know only as a cold scientific fact; and if history repeat itself there may be latter-day worshippers of the sun, the great source of all life and power in our portion of the universe. The following figures may give you some idea of the sun's magnitude. From the earth to the moon is a little step of about thirty times the earth's diameter. The quick train on the Great Western Railway in England, known as the Flying Dutchman, would do the distance in about five months, or the time it used to take to go from England to India in the old East Indiaman. You can imagine the moon circling round the earth at a distance of 240,000 miles. Picture to yourself an enormous globe filling up the moon's orbit. This *enormous globe* would be *one-sixth* the volume of the mighty sun. Here in South Africa it is less difficult to grasp the idea of the sun's intense power than in some countries. In England the sun may be said to be a summer visitor. England is kept alive by hot water like a green-house. Here the situation is just reversed. We are rather too near the sun for our own comfort, or for the best development of the animals and plants we have brought with us, from higher latitudes. But the hot sun to the north of us is tempered by the great waste of cold water to the south of us. It is true that there is the warm Agulhas current from the Indian Ocean, sweeping round the eastern and southerly coast of the Colony. But the great atmospheric current from the south-east is not, we know, much affected by crossing the comparatively narrow Agulhas current. Thus, while England lives by the combined heat of a tempered slanting sun and of the Gulf stream, we, but ten degrees removed from the overpowering vertical sun of the tropics, experience only an ever-bright sun tempered by cool airs from the southern ocean. What the sun is to the earth, we, in these latitudes, can appreciate far better than dwellers in high latitudes. It follows also that parts of the earth situated more directly under the sun will feel at once any variation in the sun's power, while countries at a greater distance from the equator will feel the same influence indirectly and second-hand through the agency of masked and distant meteoric influences. Such we shall see presently is the fact, when we come to consider the various influences of sun-spots on mundane affairs. The following extract from the "Edinburgh Review" gives the most recent information on the actual heat power of the sun :—

"A considerable amount of scientific labour has been devoted during recent years to form some reliable estimate as to the temperature of the radiant surface of the sun. The investigation, however, is so subtle and difficult that no absolute conclusions have yet been arrived at in regard to it. Sir Isaac Newton thought that the heat of the sun was at least two thousand times greater than the temperature of red hot iron. Pouillet calculated a temperature somewhere between 2,600 deg. and 3,170 deg. Fah. as the probable amount of the sun's heat. Prof. Langley, from observations made with his recently constructed bolometer, or ray-measurer—a very sensitive instrument in which calorific vibrations are converted into electric currents—gives, as a probably exact result, from 1,800 deg. to 2,000 deg. centigrade; and, by a very beautiful series of experiments of an altogether independent nature, he satisfies himself that the sun's hemisphere radiates 87 times as much heat, and 5,300 times as much light, as an equal area of incandescent steel in a Bessemer converter, in which the air-blast has been sustained for about twenty minutes. This may perhaps be looked upon as the most trustworthy approximation to any definite conclusion that has yet been found possible in this very difficult branch cf human knowledge. Its large amount, at any rate, very satisfactorily accounts for the enormous quantity of work that is done upon the terrestrial surface by solar heat, after its journey of 93 millions of miles across the gap which separates its source from the earth."

This is a popular description of the heat power and the light power of the sun; but, after all, the figures are far too large to be grasped. This we must endeavour to remember, that the intense heat and light of the sun are something stupendous and something gigantic beyond conception. Take the pictures of all the old masters pourtraying the eternal agonies of unregenerate souls; string together the fervid outpourings of the mediæval poets on the fires of Hades and purgatory, and these will give you but a dull and distant conception of the actual light and heat which the sun is for ever pouring forth, on every side, into space!

However faintly one grasps the idea of the intense energy dissipated by the sun, the further reflection inevitably follows, whence arises the sun's energy, and how long will it last? How far distant is the day when the Arctic regions of our earth shall gradually extend towards the equator, and wrap all nature in an icy pall? Sir William Siemens is the father of a recuperative theory of solar heat, which does not appear to be generally accepted, and which, indeed, has objections on the face of it. The view more generally accepted by astronomers is that the sun is very very slowly using up its energy. Most of us can remember from our school days the simple rule that matter when forced to contract evolves heat; and the converse, that matter expands when heat is put into it, we see happening around us everywhere. Now the sun, it is held, is gradually shrinking in bulk; this shrinkage is its magazine of energy. It is calculated that the yearly expenditure of heat and light from the sun would be made up by a contraction of 300 feet in its diameter. "In five million years," says Miss Clerke, "the sun will have contracted to half its present bulk. In seven million more it will be as dense as the earth. It is difficult to believe that it will then be a luminous body." The weak point of this theory is that the period of life, past and future, allotted to the sun, is too short both for biology and geology. Prof. Helmholtz, the talented author of the shrinkage theory, "looks upon the entire life of our solar system as being most probably comprised within a period of something like thirty million of years. The sun itself is held to be a sticky mass of condensed gases, its substance being of a viscous nature resembling treacle or honey. The original colour of the sun is blue, the slightly yellow tint of the sun as we see it being due to the absorption of the light in passing through the sun's atmosphere and our own atmosphere. About half the sun's heat as it reaches us, is absorbed in its passage through our atmosphere. With these observations on the sun I hope the way is sufficiently cleared for what we are here to consider this evening, namely, those spots on the sun's disc which have been found to exert such a remarkable influence on the climate of our earth.

Nothing certain was known of sun-spots till the invention of telescopes enabled observers to look on the face of the mighty sun. In 1612, Galileo published in Florence an account of certain dark spots which he had noticed on the sun. These dark spots had appeared at one edge of the sun's disc, travelled gradually across, and then disappeared at the opposite edge. Their rate of motion was most rapid at the centre of the disc. From this it became tolerably clear that the spots themselves were fixed, and that the sun itself had a motion of rotation. From observing the rate of motion of the spots, Galileo came to the conclusion that the sun made a complete rotation in a little under a month. Galileo observed also that the spots were restricted to a "royal zone," 30 deg. north and south of the solar equator. The discovery met with the usual opposition from the clergy, one of whom declared that the sun was the eye of the world, and as such could not suffer from ophthalmia! For more than a century and a half after Galileo's death, nothing further was discovered about the sun or its spots.

At last, in 1769, Prof. Wilson again resumed the study of sun-spots, his attention being arrested by a spot of unusual magnitude, which he watched cross the sun's disc till it disappeared on the western side, and which he recognised again when it reappeared on the eastern side. Five years afterwards he announced that the sun's spots which had so long baffled astronomers, were simply gaps or holes in the luminous atmosphere, which he assumed surrounded the dark body of the sun. This idea of a luminous envelope was elaborated by the elder Herschel, the father of the Sir John Herschel, whose name, let us hope, will ever remain a household word in Cape Colony. Before we enter upon the hard facts of what there is in the sun and what sun-spots are, let me read you a description of what Sir William Herschel conceived the sun to be—a pretty poetical fancy that has been rudely swept away by the knowledge of our day. I shall read you a quotation from a charming recent work on popular astronomy by Miss Clerke :—

" Sir John Herschel conceived the sun to be a cool, dark, solid globe, its surface diversified with mountains and valleys, clothed with luxuriant vegetation, and richly stored with inhabitants, protected by a heavy cloud-canopy from the intolerable glare of the upper luminous region, where the dazzling coruscations of a solar aurora some thousands of miles in depth, evolved the stores of light and heat which vivify our world. The sun-spots were held to be gaps in the shining envelope through which we looked on to the cool globe below."

A few years after the promulgation of the elder Herschel's theory of the physical constitution of the sun and its spots, came the invention of the spectroscope. This speedily showed what the sun really is. Not a cool globe surrounded by a luminous atmosphere, but a huge fiery mass glowing with a heat so far more intense than the hottest of our furnaces, that to realize it we must toy with the imagination, as we do when we faintly try to grasp the magnitude of astronomical distances. We now come to the discovery of the grand fact that sun-spots are not stray visitors on the sun's surface, but that they come and go in regular periods of about eleven years.

It is exactly sixty years since the first systematic enumeration of sun-spots was undertaken by a German apothecary, Hofrath Heinrich Schwabe, of Dessau. For years he worked alone, unaided and unencouraged, not being himself fully aware of the importance of the discovery at which he was toiling. Speaking of him Miss Clerke says:

During forty-three years his "imperturbable telescope" never failed (weather and health permitting) to bring in its daily report as to how many, or if any, spots were visible on the sun's disc, the information being day by day recorded on a simple and unvarying system. In 1843 he made his first announcement of a probable decennial period, but it met with no general attention; Schwabe, however, worked on, gathering each year fresh evidence of a law such as he had indicated; and when Humboldt published in 1851, in the third volume of his "Kosmos," a table of the sun-spot statistics collected by him from 1826 downwards, the strength of his case was perceived, with, so to speak, a start of surprise; the reality and importance of the discovery were simultaneously recognised, and the persevering Hofrath, of Dessau, found himself famous amongst astronomers. His merit—recognised by the bestowal of the Astronomical Society's gold medal in 1857—consisted in his choice of an original and appropriate line of work, and in the admirable tenacity of purpose with which he pursued it."

Among the illustrious band of scientists to whom in these days of light has been given the immortal honour of advancing by a step the world's knowledge, few characters to my mind stand out with a brighter radiance than that of Schwabe. He toiled during long years with the dogged perseverance of his race, and he lived to see his life's work crowned with the glory of a discovery, the importance of which is ever becoming more and more apparent.

In 1870, Dr. Rudolph Wolf collected the various materials available, and published a list (which we shall refer to presently), giving eleven complete cycles of sun-spots from 1750 to 1870. Now, in every civilized country, observers are at work noting and photographing, the appearance of the sun's disc. In 1882 there were as many as 144 officially recognised observatories, at work on the sun's disc, in the United States of America. From the published accounts of this and similar work you will doubtless recall the important part now played by photography in these observations. The photographic film can register appearances and ray vibrations to which the human eye would be insensible. In recent years the most successful European observations of sun-spots and solar manifestations, have been made in the clear atmosphere of Italy. We have noticed that the Herschellian conception of the sun and sun-spots was rapidly upset by the flood of knowledge let in on the subject by the spectroscope. We know now what the sun is composed of: the light coming from the sun-spots has been analyzed, and we know that they contain certain metals. But as to what sun-spots are, and what causes them, modern science as yet gives but an uncertain sound. Perhaps the best popular description of the modern conception of sun-spots is that they are clouds, eruptive clouds, such as those one sees from Naples crowning the summit of Mount Vesuvius. I may perhaps mention briefly two theories that have been advanced to account for the formation of these sun-spot clouds, one theory chemical, and one mechanical. The chemical theory supposes the eruption of transparent metallic vapours such as calcium, sodium and potassium, and gases for which these metals have a strong affinity ; a lowered temperature permits their union and the deposit of opaque clouds of heavy particles, which, as soon as they are formed, fall by gravity into the glowing mass of the sun's sphere, where they are once more resolved into their elements.

On the mechanical theory the simple eruption of vapours would cause clouds by cooling and condensation, exactly as the clouds are found on Vesuvius. The eruption of these vapours is accounted for thus. Matter in the sun is held in equilibrium, counterpoised, as it were, between two opposing forces. The attraction of matter by matter which tends to bind the sun's mass closer together, and the intense heat which tends ever to vapourise and disperse the sun's mass. Any little disturbance of this equilibrium must cause eruption or contraction. It is these eruptions which we see as sun-spots.

Of the behaviour and appearances of sun-spots we have more precise knowledge. Writing a few weeks ago in "Nature," Mr. Norman Lockyer thus summarizes the recent work on this subject :—When we have the maximum period of sun-spots, the latitude (solar) of the sun-spot zone is between 8 deg. and 10 deg., but it gets much lower than that when the period is closing, and even before one period has closed another one has begun in a higher latitude, so that the swirl in the solar atmosphere seems to begin in a high latitude—say 30 deg. or 35 deg., or thereabouts—and very soon gets into full swing in latitudes between 10 deg. and 12 deg., and then it gradually dies away, until spot and metallic prominences and faculæ cling pretty near to the equator, and then we get a new wave of activity beginning again in a high latitude.

Dr. Peters, an authority on sun-spots, describes thus the appearance they present when they first appear on the sun :—" The spots arise from insensible points, so that the exact moment of their origin can not be stated ; but they grow very rapidly in the beginning, and almost always, in less than a day, they arrive at their maximum of size. Then they are stationery, I would say in the vigorous epoch of their life, with a well-defined penumbra of regular and rather simple shape. So they sustain themselves for 10, 20, and some even for 50 days."

Other observers give sun-spots four or five days and sometimes a week to attain their maximum size, but this we may note that, beginning with dots, scarcely perceptible with a powerful telescope, sun-spots grow rapidly in a day or two to a large size. Sometimes they are so large that you can see them with the naked eye through a bit of smoked glass. The actual magnitude of spots seen at such an enormous distance is, of course, stupendous. We read of spots, or patches of spots, which are as much as 140,000 miles in length, or eighteen times the diameter of our earth. Or to put this another way. Imagine eighteen worlds breaking out all over with volcanos. The light and heat of such a disturbance would travel a long way, would it not ? This is one good-sized sun-spot. When there are many such spots at work, you can imagine the influence being felt even in our far off insignificant little world. The pictures on the wall represent sun-spots as they look through the powerful telescopes used by astronomers. The first is taken from a lecture given recently by Norman Lockyer. The second is a photographic enlargement of an original photograph by the celebrated French observer Jansen.

The third drawing represents the end view of a sun-spot, seen edgeways as the spot is disappearing, with the rotation of the sun's disc. Such a photograph as this certainly supports the view that sun-spots are depressions in the sun's shining outer envelope—what is known as the photosphere. These depressions, you will remember, are considered to be caused by descending clouds of condensed metals or chemical combinations. This third photograph was taken at Dehra Dun in India two years ago.

The sun presents other appearances, all of which share the peculiarity of sun-spots, namely, that they wax and wane in periods of eleven years. Of these I can now only mention the solar prominences and red flames which are thus described in a valuable article that appeared some years ago in the "Nineteenth Century," after the last famine in India:—

"Strange forms are also seen, exquisite in colour, fantastic beyond description in outline, and of stupendous magnitude. These are the solar prominences or red flames, the existence of which was formerly revealed to us in eclipses only. Like the spots, and like the eruptions, they wax and wane. At one time a dozen may be visible round the edge of the sun, some of them a hundred thousand miles high; at other times there is scarcely the most feeble indication of this form of solar activity."

The solar prominences are of two kinds:—

The quiet or forest-like prominences.

The eruptive or flame-like prominences.

Here is a picture of the forest-like prominences. From their appearance they are often called cloud prominences. The spectroscope shows that these forest-like prominences are of simple constitution. They are in fact clouds of hydrogen and helium which float a vast height above the sun's chromosphere.

The flame-like prominences, on the other hand, are composed of a number of elements: iron, sodium, magnesium, barium, calcium, &c. Hence, Norman Lockyer's term of metallic prominences. They are visibly of eruptive origin, and in their coming and going on the sun's surface are closely related to sun-spots. They have the same cycle as sun-spots, but their maximum period lasts longer than that of sun-spots. *Our South African periodicity of climate corresponds more closely with the solar prominences than with the spots.*

Another appearance frequently discussed in works on solar physics is that of faculæ. I may mention that faculæ are shining, dome-like prominences, very intimately connected with sun-spots. Indeed, they are sometimes described as playing an essential part in the life history of sun-spots.

To the question why sun-spots and other solar manifestations should wax and wane in regular cycles of eleven years, science as yet gives no answer. Sir William Herschel, who, while he was at the Cape, in our clear atmosphere, worked long and earnestly at sun-spot observations, supposed that they were caused, or largely influenced, by the planet Jupiter. This, the largest of the planets, revolves round the sun in 11·9 years, which is very near the sun-spot cycle of 11·11 years. But, as Miss Clerke observes, "it does not seem that the most skilful coaxing of figures can bring about a fundamental harmony." During eight successive periods, from 1770 downwards, there have been approximate coincidences between Jupiter's aphelion passages and sun-spot maxima, but the relation was exactly reversed in the two years preceding that date. Mr. Wolf's latest conclusion is that the Jovian origin of sun-spots must be abandoned. Nevertheless, it is certain that sun-spots and other solar appearances are influenced to some extent by the earth and by its fellow-planets Jupiter, Venus, and Mercury, the action of Venus being the most marked.

We must then await the further researches of science to show us why the sun-spots, the solar prominences, and other signs of the sun's activity increase and decline in cycles of eleven years.

INFLUENCE OF SUN-SPOTS ON OUR EARTH.

We come now to the practical part of this paper, that is to say, the influence exerted by sun-spots on the affairs of our earth. These I shall consider under three heads:—

1. The influence of sun-spots in countries such as South India, which receive the largest share of the sun's light and heat.
2. The influence of sun-spots in countries like England and Northern Europe and America, where the sun is powerful only for a portion of the year.
3. Sun-spot influence in South Africa, which may be considered to occupy an intermediate position between England and South India.

To begin with sun-spot influence on magnetism, we find here a strong and direct influence exerted in all the three classes of countries. The influence of sun-spots on magnetism has been long and closely studied by scientific men, in India, in Europe, in England, and in America, with a happy unanimity of results which it is pleasing to dwell upon. Right in the south of the peninsula of South India there was a celebrated observatory at Trevandrun. This has supplied figures of magnetic observations extending back a quarter of a century which show an indubitable correspondence with sunspot figures. The beautifnl aurora displays of the North and of the South Poles are a magnetic phenomenon, and have been found to be most frequent and vivid during years of maximum sun-spots. A magnetic needle freely suspended points, as everyone knows, north and south. A simple bar of steel suspended in the same way becomes a magnet by induction from the earth's magnetism. But a freely suspended magnet not only points north and south, but, influenced by the earth's magnetism, shows small independent motions. There is a regular magnetic variation depending on the time of day, and there are irregular spasmodic movements, giving observers an index of the magnetic forces acting in the earth. The records of these magnetic movements and of auroras have been examined by Professor Balfour Stewart from 1776 to 1872, and his verdict is that the magnetic movements, both spasmodic and diurnal, and the auroras, show a close correspondence with sun-spots, taking of course average figures over a term of years. There is more than this. Individual outbreaks of sun-spots are followed by individual manifestations of magnetism on the earth. You will doubtless recall accounts published from time to time of magnetic disturbances which affect the telegraphs and the compass used by mariners and surveyors. Of greater practical interest to us are those thunderstorms which burst over us every summer, ruining crops and occasionally killing men and animals. Now, all scientific observation goes to show that electric and magnetic disurbances such as these follow all over the earth directly on sun-spots. The maximum rainfall in this part of South Africa seems to follow two or three years after maximum spots, so that happily our worst thunderstorms and our best crops should not come together.

SUN-SPOTS INFLUENCE ON WINDS.

There are probably few windier countries in the world than South Africa. Nowhere is the action of sun-spots on the meteorology of our earth clearer than in the close connection between sun-spots and tropical winds. I can remember when a student at St. Andrew's University in Scotland hearing of the discovery made by Dr. Meldrum, of Mauritius, that there was a close connection between sun-spots and the hurricanes of the Indian Ocean. I have been in the Cape Colony for three years. I have not been silent on the subject of sun-spots and rainfall, yet I cannot recall having conversed with anyone who allowed it to be perceived that he was conversant with Dr. Meldrum's great discovery. It is not a very far call from here to Mauritius. Most of our rainfall comes (with wind disturbances travelling in an opposite direction) more or less directly from the Indian Ocean, so that the fact is of importance to a country whose welfare hangs on its rainfall. The colony spends over £80,000 a year on education! How many children could give an intelligible account of the relation between sun-spots and cyclones in the Indian Ocean! Dr. Meldrum's discovery was this. He showed with a conclusiveness that has never been called in question, the intimate connection between sun-spots and hurricanes. Norman Lockyer, the astronomer, writing in 1872, thus describes Dr. Meldrum's discovery: "Dr. Meldrum tells us that the whole question of cyclones is a question of solar activity, and that if we write down in one column the number of cyclones in any given year there will be a strict relation between them—many sun-spots, many hurricanes; few sun-spots, few hurricanes. Dr. Meldrum points out that in those years in which we have been quietly mapping out the sun-spot maxima the harbours were filled with wrecks and vessels coming in disabled from every part of the great Indian Ocean."

Similar but not equally strong figures show the connection between sun-spots and wind disturbances in the West Indies. Pursuing the same enquiry, Sir J. J. Hunter, an eminent member of the Indian Civil Service, elicited the curious fact that throughout the world there was a larger percentage of shipwrecks during years of maximum sun-spots. This conclusion was arrived at after tabulating and comparing the Loss-book kept at Lloyd's, in London, for two sun-spot cycles. The connection is probably caused by wrecks within the tropics.

It is unlikely that there is any close connection between sun-spots and wind disturbances in high latitudes. But it is highly probable that there is some connection in extra-tropical latitudes, such as the Cape Colony. I have, however, seen no figures bearing on this subject.

INFLUENCE ON TEMPERATURES.

We come now to the effect of sun-spots on mean temperatures. This, which at first sight would appear so easy is quite the most unsatisfactory aspect of sun-spot literature. When one thinks of the sun pouring its heat so steadily into the black bulb of the thermometer shielded as this is from disturbing atmospheric influences by the vacuum bulb in which it is immersed,—to use a familiar expression, it all seems as plain as a pikestaff. The sun is hotter at the maximum spot period, and that black bulb thermometer must show it. But the black bulb thermometer does not show it, and from observatories all over the world come conflicting reports. Happily this is easy to account for without impugning the veracity of sun-spots. Three-fourths of the earth's surface is occupied by water. The remaining fourth part is always more or less moist, and carries rivers, lakes, forests and vegetation of all kinds. An average tree, especially if it stands alone, evaporates very much more watery vapour than an equal horizontal expanse of water : thus on the earth's surface there is evaporation of watery vapour going on almost everywhere. An increase in the sun's power means increased evaporation, more cloud, and consequently a lessened apparent heat reaching the black bulb of the thermometer, or similar instruments employed to measure the sun's radiant energy. In the tropics where the sun is always practically vertical, the only variation in its power is when it is screened by clouds. There the coolest time of the year is the rainy season, and the years of least solar radiation should be the year of maximum spots and maximum evaporation. And, continuing the cycle, minimum spots should correspond with maximum sun power. This is in fact what, without going closely into the subject, the figures show. From the far greater abundance of water in the southern hemisphere, it might be supposed that this rule of inversed temperature corresponding with sun-spots, would find some confirmation from even extra-tropical observatories in the southern hemisphere. This confirmation comes from the Cape Town Observatory. The returns for thirty years from the Cape Town Observatory show a close correspondence between sun-spots and temperatures the maximum of temperature lagging a year behind the minimum of sun-spots. The curves have been plotted and published by Mr. Stone. In England again, where the sun is nearly always shining through clouds, the mass of which cloud in so high a latitude is very indirectly (if at all) affected by sun-spot variation, we find as would be expected, a slightly increased solar radiation corresponding directly with sun-spots — maximum sun-spots with maximum sun-power. This comes out on various lines of enquiry:—The Solar Radiation Registers kept at the Radcliffe Observatory, Oxford, from 1856 to 1864. Winter temperature range at Kew is greatest with maximum sun-spots. There is more sunshine at London at maximum than at minimum spot periods. So much for England's sun, but England's Gulf Stream comes from sunny latitudes where sun-spots may be considered to act inversely on temperatures. Thus Edinburgh observations on thermometers sunk in the rock show that a great heat wave occurs every eleven years, its maximum slightly lagging behind the minimum of the sun-spot cycle.

Except perhaps from an observatory on one of the tropical summits of the Andes, there seems little hope of obtaining any direct measure of the periodical variation of solar radiation. The earth is wrapped in its atmosphere as in a blanket. This atmosphere is ever varying. On one day it shuts off part of the heat rays; on another part, of the light rays; on another, part of the chemical rays. Of the presence of these invisible chemical rays we have evidence in some cases of sunstroke. These have been known to occur, rarely in this country, more commonly in India, when there was no visible sun out. On such days as these a great part of the light rays and some of the heat rays are absorbed, but the dark chemical rays remain. On the other hand I have known not more than ordinary dull days, when for several days together, sensitive silver paper acquired but very faint lines, showing that on these days the atmosphere had absorbed nearly all the chemical rays. The atmosphere absorbs now one part of the spectrum, now another. And if our solar thermometers show no increased heat received from the sun during years of maximum sun-spots and solar activity, it is easy to see why the thermometers are silent.

INFLUENCE OF SUN-SPOTS ON RAINFALL.

It is in the influence of sun-spots on rainfall that centres the practical interest of people in South Africa. The earth yields her increase and the people of this country are prosperous just in proportion to the rain that falls. We will now examine the influence of sun-spots on rainfall, first in a tropical country India, then in the cold temperate climate of Europe, and finally in the warm temperate climate of South Africa.

The part of India of which I shall now speak is the south, occupied by the Presidencies of Madras and Bombay. Compared to Cape Colony, it is densely populated, and richly cultivated. But the bulk of the population are miserably poor, and when the regular monsoon rains fail, as they do fail, from time to time, there occur those terribly widespread miseries which you hear of as famines. Of the horrors known to our civilization it is tolerably certain that there is nothing more terrible than an Indian famine. In the province of Mysore where I was serving during the famine of 1876, there perished one and a half million people out of a population of a little over five millions. Disease and death stalked over the land, and in a few months a prosperous province became a vast charnel house. After the famine the connection between sun-spots and famine which had for some time been known was closely and earnestly studied. A remarkable paper written jointly by an astronomer and a statician—Messrs. Norman Lockyer and Hunter—appeared in the "XIX Century." From the figures supplied by this article most of the sun-spot influence curves, shown in the lecture-diagrams have been constructed. Going back as far as 1810 these gentlemen present us with a strong series of figures showing clearly and unmistakeable the intimate connection between sun-spots and famines in Madras.

The diagram before you shows the sun-spot curve compared with the rainfall curve plotted from the Madras Observatory figures. These curves speak for themselves. They show graphically and accurately how the rainfall in Madras is influenced by that solar activity of which sun-spots are the most convenient index. Taking average figures over a long term of years, so as to avoid all possibility of chance coincidences, you see the exact extent to which the sun-spot curve follows the rainfall curve, the one rising and falling with the other. Messrs. Norman

Lockyer and Hunter also obtained a list of all the notorious famines in Madras during this century. They compared this list with the sun-spot cycles and found that the two ran parallel in a very remarkable manner. Thus the last great famine, which I have referred to already as happening when I was in India, was in 1876 a period of minimum sun-spots. The famine previous to that was in 1865, *or exactly* 11 *years before.* The famine previous to that was in 1853—*an interval of 12 years*—bringing the famine still well within the minimum period. In 1843 the next dangerous period, Madras escaped an actual famine. But in going back another eleven years, there was again famine in 1832. At the next eleven year period there was a late sun-spot minimum and with it came a late famine in 1823. In 1810 again at the exact point in the cycle Madras had another famine. These figures appear to me very strong. They extend back over half a century, and thus, the most sceptically-disposed person cannot say that it is by chance that every eleven years at the minimum sun-spot period, Southern India has either had famine or has barely escaped it. Perhaps it will make it clearer to put these figures side by side, thus :—

Observed years of minimum Sun-spots.	Theoretical years of minimum Sun-spots.	Years of Famine.
1810	1811	A Famine at the observed extreme min. period
1823	1822	do. do. do.
1833	1833	A Famine at the exact minimum period.
1844	1844	No notorious Famine.
1856	1855	A Famine in 1853, the drought lasting till 1885.
1866	1866	A Famine in 1865.
1876-78	1877	A Famine 1876-77.

Scrutinizing these figures it will be seen that on an average Madras famines tend to recur about one year before the extreme minimum theoretical period. This is natural enough in a country so situated that it would feel at once the downward tendency of the sun-spot curve.

"There have been" say Messrs. Hunter and Norman Lockyer, "other years of scarcity at Madras. But the above six years were selected by Sir William Robinson, some time Acting Governor, as the years of true famine, without any acquaintance with the writers' speculations on the rainfall, or of any cycle being supported or disproved by them."

This much is absolutely certain, that taking figures over a term of years as the spots wax and wain on the sun's surface so does the rain on the Madras coast. At other stations in southern India the sun-spot cycle influence can be traced in the rainfall returns notably in those from Mysore. Probably this influence will come out more clearly as the rainfall registers are extended and strengthened. On the upland plateau of Mysore which lies inland from Madras, and gets a nearly equal allowance of rain from both the east and the west coasts, I found that there was a close correspondence between the *average price of food grain* and the *average number of sun-spots.* Many sun-spots: good rains and cheap grain. Few sun-spots; bad rains and dear grain.

Going a little further from the equator, we get a strong series of figures from the Bombay Observatory extending back to the year 1817. Here the correspondence between sun-spots and rainfall is as close as at Madras but, as we shall see presently is the case with the Cape Town figures, the rainfall lags a year behind the sunspots. In northern India, at a distance from the evaporating surface of the great ocean, and where the stupendous chain of the Himalayas introduces a disturbing element, there appears to be only a slight and that a reversed connection between sunspots and rainfall. There is certainly not the close correspondence that exists in southern India, a correspondence to which I wish to call your especial attention to-night, on account of the connection between the physical features and, in many respects, the meteorology of South Africa and of southern India. The mean rainfull in Madras is:—

In years of Maximum Sunspots	...	53·50 inches
" Minimum "	...	40·39 "

Or, on an average, the rainfall in maximum sunspot years is greater by 13 inches than in minimum sunspot years. Next year, 1888·8, will be the year of minimum sunspots, when famine is most to be feared. We cannot say that there will then be a famine in southern India, but we know that there is a strong chance of it. A prudent man of business buying rice in India, would anticipate a notable rise in prices, and buy accordingly. Let me illustrate my meaning. I referred recently to the fearful famine which happened in 1876-77 in southern India. In 1882 there were some signs of the rains again failing. With the horrors of the '76 famine still fresh in men's mind, the dread of another such calamity began to make itself felt, and famine measures to be discussed in the public prints. On that occasion I wrote an article in the *Madras Mail*, the leading organ of southern India, pointing out two reasons why there was little fear of a famine happening then. (1) 1882 was a year of abundant sunspots, it was close on the maximum spot year of 1883 ; (2) For several years previously the rainfall had been below the average. I gave a series of figures showing how closely the average prices of food grains in Mysore corresponded with the sunspot cycle. This prediction was happily verified. Good rains fell two months afterwards and all fear of famine passed away.

Again when I came to South Africa in 1883 it was to repeat this experience. There had been drought for so many years, that it was almost a certainty that the drought could not last for many years longer. Believing in sunspot influence in these latitudes I was at first surprised that we were already so far past the maximum without having had good rain. Looking, however, into the meteorological records, this very soon became clear. The Cape Town rainfall lags slightly behind the sunspots. Our Eastern rainfall lags about two years behind the western seasons. The last heavy rainfall and floods here in the east had been at the end of 1874. A similar season we shall see presently had been experienced in 1863. It was natural therefore to suppose that we might look for good rain again towards the end of 1885. How surprisingly punctually it came everyone here to-night remembers!

Now in both of these instances there was nothing more than the strong chance that the rain would come when it did. And similarly there is a strong chance of famine happening next year or within a year or two in Madras. No one can speak positively or precisely with regard to such an event, but the chances of its happening are sufficiently strong to make it a factor which no wise man would neglect in entering into the forecasts and calculations of ordinary life.

SUNSPOTS AND RAINFALL IN EUROPE AND COLD COUNTRIES.

Near the Equator the weather depends directly on the all-powerful sun ; but at a distance from the sun, as we noticed when speaking of temperatures, the action of the sun on rainfall is indirect and so masked that we know not exactly how it influences rainfall Ten or twelve years ago the meteorological records of Europe and North America were ransacked, sifted, and grouped in a variety of ways, with a view of examining the supposed influence of sunspots on rainfall.

A German enquirer, Gustave Wex, traced a resemblance between, the average height of the water in the Danube, the Rhine and the larger German rivers, and sunspot variation. He found maximum spots corresponded with maximum water in the rivers. He took his figures back to the early part of this century and I cannot recall that they have been upset. A similar correspondence was traced between sunspots and the average maximum and minimum water in the great lakes of North America. Correspondences have also been traced between sunspots and the rain-guage returns of many stations. But in almost an equal number of cases, these attempted correspondences have failed, and the net result of extended enquiry and much writing on this subject is to my mind the Scotch verdict of " not proven."

Schwabe the discoverer of sunspots could trace no connection between sunspots and the meteorological data and we may take it, I think as definitely established that in countries at a distance from the equator, the correspondence between sunspots and rainfall ceases to have any practical value.

SUNSPOTS AND RAINFALL IN EXTRA-TROPICAL LATITUDES.

We have seen how strong is the influence of sunspots on rainfall in southern India, how weak and conflicting in northern Europe. In extra-troptcal latitudes like that of Cape Colony, it would be natural to expect an influence midway between the two. And this appears to be the case, bearing in mind the fact that when the rain is brought by winds blowing from the equator it would be more likely to have a cyclical character than when it is mainly brought by winds blowing from high latitudes. From this we should expect a stronger sunspot influence in the east then in the west of Cape Colony or than in the southern settled portions of Australia. The Australian climate is favourably tempered, by winter rains, by prevailing southerly winds, and by ocean currents from higher latitudes, but these would not be favourable to sunspot influence. It does not appear that the Australian droughts correspond as closely as do those in South Africa with the sunspot cycle. The 19th Century article referred to above says:—" Dr. Meldrum, from a comparison of the rain return at Mauritius, Adelaide and Brisbane, came to the conclusion that the evidence of a connection between its maximum and minimum periods, and the correspouding sunspot period, although not absolute, was very striking and demanded further enquiry."

In the west of Cape Colony the bulk of the rain as in South Australia falls during winter. At Cape Town there is a cold southern sea current in place of the warm tropical current of this coast, but almost the whole of the rain comes with the great atmospheric movement from the N.W., which prevails in South Africa during the winter months. Thus it would be natural to suppose that at Cape Town sunspot influence would be apparent but less so than in the east of Cape Colony where the rain comes during summer and more or less directly from the Indian Ocean where, as we have seen sunspot influence is so powerful. At Cape Town, the correspondence between the mean rainfall and mean sunspot frequency has long been an established fact.

*What that correspondence is can be seen at a glance by inspecting the sunspot curve and the rainfall curve, shown together on this diagram. The yellow line rising steeply to a maximum and falling away gradually to a minimum is the sunspot curve—a curve which ought to be graven on the mind of every man and woman in South Africa. If our merchants had had this curve in their heads they would have hesitated before shipping mealies from South America at the end of 1885, when there was such a strong probability, amounting to almost a certainty, that the breaking up of the drought was impending. The blue curve shows the average rainfall at the Cape Town Observatory. To us, in the different climate of this eastern side of the colony, these figures are important from the fact of the well established relation that exists between our climate and that of the west of the colony. Their seasons usually precede our seasons. When we hear of a drought breaking up in the west, men look for rain here in the east. And, taking the year through, their weather is the complement of our weather. When we have a dry month they have a wet month and *vice versa*. This comes out remarkably in Mr. Gamble's rainfall curves, and very curiously in one instance. I allude to the July rain which has fallen so abundantly this year. Looking at the three western stations, Cape Town, Wynberg, and Bishop's Court, shown on this diagram you will notice a depression in the curve of average rainfall for the month of July. Looking at the three eastern stations placed opposite the western stations on this diagram you see that at Grahamstown, at King William's Town, at Queenstown, and at Somerset East, we have a little rise in our rainfall curve corresponding with the depression in the western rainfall curve.

***The later views of the writer will be found developed in the second lecture.**

For these reasons we ought to consider the Cape Town Observatory rainfall figures as of great importance to ourselves, an importance enhanced by the fact that they go back to the year 1842. For the three cycles comprised in the period 1842 to 1875 the mean annual rainfall at the Royal Observatory, Cape Town, was :—

During	Minimum Sunspot	years	21·05	inches.
„	Intermediate	„	23·59	„
„	Maximum	„	27·95	„

Coming eastward we find that the rain-gauge returns are too recent to afford reliable averages. From Grahamstown where observations have been taken the longest, the returns extend over only two complete sunspot cycles For King William's Town we have only one complete sunspot cycle. I have therefore continued the investigation in a different channel.

We have seen that in the case of the Madras famines, remarkable figures were disclosed by Messrs. Norman Lockyer & Hunter, when they came to compare years of notorious famine with the sunspot cycles. All the bad famines in Madras during the past half century have been at minimum sunspot periods. I have endeavoured to follow out something of the same line of enquiry here, and for this purpose have consulted the following gentlemen :— The Hon. C Brownlee, the eminent Transkeian Magistrate ; Dr. Stewart, of Lovedale ; Rev. W. R. Thomson, of Balfour ; Rev. R. Birt, of Peelton. Comparing together the dates of remarkable seasons which they have courteously furnished, I have compiled the following list. I should perhaps state that these dates were furnished by Messrs. Brownlee, Thomson and Birt without any previous knowledge of my speculations on the sunspot periods :—

1821-22.—Messrs. Brownlee and Thomson describe great floods ending a period of drought. The sufferings occasioned by these floods are mentioned also in the accounts of the Albany settlers. This rain happened at the minimum of sunspots. Its occurrence at this period will be found explained in the second lecture.

1828.—In this year there were floods according to Mr.

Thomson; great floods according to Mr. Brownlee who says:—"The Buffalo rose very suddenly to a great height and when the waters receded great quantities of fish were left in the grass above the banks." This was at the exact maximum sunspot period or three years before the greatest expectation of sunspot rain. Though less so than in the preceding cycle the sunspot maximum was still a weak one.

1839.—There was a great drought in 1839 followed by rain in 1841 or '42. These were the years of greatest expectation of sunspot rain. The maximum was a strong one—the strongest during the present century up to that date. It came in 1837 one year before its time.

1847-48.—There were floods in 1847 according to Mr. Brownlee; in 1848 according to Messrs. Thomson and Birt. The recollections of the two latter gentlemen coincide in placing these floods in March 1848. Great damage was done to crops. All our eastern rivers were in tearing flood. Amidst the disasters of this time, a ludicrous incident is mentioned, of a four poster bed, complete with blankets and pillows, being seen floating over the tops of the Beaufort bridge. The theoretical maximum was in 1849, the observed maximum in 1848; so that the floods coincided with the year of actual maximum sunspots. This was a strong maximum though not so strong as in the preceding cycle. There was then a period of good seasons extending, according to Mr. Birt, with one slight interruption from 1846 to 1856. The greatest expectation of sunspot rain was in the middle of this period in 1852. Mr. Brownlee speaks of very wet seasons and floods in the Buffalo in 1854 and 1855.

1862-63.—An exceedingly wet season, following a drought which was most severe about 1861, according to Mr. Brownlee. Some brick-makers at work on an island on the Buffalo River were rescued by a boat. This season is only two sunspot cycles back and I have similar recollections as to its character from other people. In 1863 Mr. Brown, the well-known author of works on Forestry, paid a visit to the Eastern Province. He gives a graphic description, in his Hydrology of South Africa, of the flooded state of the rivers in that year and of the quantity of water he saw pouring away unutilized to the sea. 1862-63 were the exact years of the greatest expectation of sunspot rains. The actual maximum occurred punctually in 1860 and was as strong as in the preceding cycle.

1874.—Mr. Brownlee speaks of good seasons in 1873, '74, and '75. Mr. Birt of the heavy steady drenching rain coming straight off the ocean from the S.E., during the early part of 1875. The floods at the end of 1874 are too recent to have been forgotton by the majority of those here to-night. The rain-gauge records give the following figures :—

Rainfall (floods) December, 1874.

King William's Town	13·01	inches.
Grahamstown	11·74	„
Queenstown	11·06	„
Somerset East	7·25	„
Graaff-Reinet	6·55	„

On this occasion there fell in King William's Town more than half the average rainfall for the whole year. And other towns similarly situated received rain in nearly the same proportion. At all of them except Somerset East the rainfall for the year was far above the average. Somerset East is quite on the border of our eastern climate.

Rainfall for the whole year, 1874.

		Average Rainfall.
King William's Town	37·12	25·72
Graham's Town	40·82	28·76
Queen's Town	28·34	20·74
Somerset East	21·04	21·45
Graaff-Reinet	21·70	14·54

There was a strong maximum of 139 sunspots in 1870 (Wolfe). It came a year before the regular period, and, allowing three years retardation, the rains came punctually.

After this, set in that drought, which, with many promises of breaking, has held the country in its withering grasp for the last nine years. Dr. Stewart speaks of deficient rainfall at Lake Nyassa in 1877-78. We know too from othe-sources that the drought was not confined to our portion of South Africa. Sunspot influence became adverse shortly after the drought set in. There has been no extra sunspot rainfall and the farmers have struggled on fighting a losing battle with a pitiless nature, till the sunspot cycle has within a few weeks of the exact date, brought that rain which has filled the granaries and turned the land into the smiling garden we had almost ceased to believe in. There is ground to hope that we shall now have a run of good years. Sunspots will be favourable for three or four years more. It is so long since there has been any remarkable sporadic or other extra sunspot rainfall that we are entitled to hope for this when sunspots become adverse. And lastly, if least, we have turned the corner with our forests. The forest area is now slowly increasing. Last year the operations of the Forest Department showed (in round numbers) over 1,000 trees reared in the nurseries for each tree cut in the forest; and only decaying trees were removed from the forest. In all the large forests in charge of European foresters the protection has been real, and the trees raised in the forest nurseries, though amounting to 140,000, are insignificant compared to the natural re-growth observable.

To recapitulate we have the following remarkable rains during the last 60 years :—

EASTERN RAINFALL.

Remarkable Rains.	*Period in the Sunspot Cycle.*
1821-22.—	Great floods occurring three years after the greatest expectation of sunspot rain.
1828.—	Great floods at the actual maximum of a weak sunspot period.
1841-42.—	Good rains occurring four years after an early strong maximum of sunspots in 1837, or at the year of greatest expectation on the 11·11 period.

1848.—Tremendous floods coinciding exactly with the early strong maximum of 1848. From 1846 to 1856 a period of almost uninterrupted good seasons.

1862-63.—Great floods two years after the actual maximum of spots in 1860.

1874.—Floods and heavy rain; eleven years since last floods. There was an early strong maximum of spots in 1870, a year before the normal period. Allowing for this and three years retardation, the rains came punctually.

1885.—After severe drought heavy rains set in within a month of the exact 11 year period. The actual sunspot maximum in 1883-84 was weak and late; rains punctual allowing for the three years retardation.

The above figures may be tabulated thus :—

Remarkable Rains.	Years of greatest expectation of rain calculated on the 11·11 spot period and 3 yrs. retardation.	Years of greatest expectation of rain fiom actual maximum of spots and 3 years retardation.	Actual observed maximum of Suuspots.
1821-22	1818	1819-20	1816-17
1828	1829-30	1831	1828
1841-42	1841	1840	1837
1848	1852	1851	1848
1862-63	1863	1863	1860
1874	1874	1873	1870
1885	1885	1886-87	1883-84

A scrutiny of this table shows that in the above six cycles the mean discrepancy between the actual and expected years of remarkable rainfall is :—

For observed max. of spots with a 3 years retardation ... 1·46 years.
For the 11·11 maximum „ „ „ ... 1·14 „

Or, in other words, of the two methods of calculating the greatest expectaticn of sunspot rain the strict 11·11 year period gives rather closer results than when the actual number of sunspots observed is taken. It must be remembered that the observed number of black spots on the sun is only one index of the solar activity. Dr. Chambers, of Bombay, declares that the curves of magnetic perturbations are more regular than the sunspot curves. Looking at the third column of the above table we see that taking the 11·11 spot period with a three years retardation, since 1818, the only instance when there was any notable discrepancy between the actual and the calculated rainfall was in 1848. This discrepancy amounted to 4 years, and may be accounted for thus. In 1848 tremendous floods coincided exactly with an actual premature and strong maximum of 124 spots (Wolfe); and good rains held right on through the period of greatest expectation of sunspot rain in 1852. Thus, in this particular instance, the discrepancy may be considered to be ccounted for, thereby reducing the mean discrepancy for the remaining years to only 0·66 of ayear, or to *a total discrepancy of 4 years in seven maximum periods compared.*

The accompanying table (page 32) shews the effect of adopting different periods of retardation. It will be seen that with the 11·11 spot period, the mean discrepancy is least—1·14 years with a retardation of three years. With the actual maximum of sunspots, the mean least discrepancy, —1·57 years, is somewhat greater; and is the same, whether a two-year or a three-year retardation be adopted. If account be taken of the time of year when the 1885 rain fell, the mean discrepancy falls slightly in favour of the three-year retardatlon.

The clock-work regularity of the rainfall during the last three cycles, 1863, 1874 and 1885, is very remarkable. We cannot of course look for the continuance of such a regularity, but to the average mind I think these figures will carry the conviction that sunspots have a potent influence on our climate.

The sunspot cycle being 11.11 years if you will reckon back for 21 cycles you will find that we come to the year 1652, the year in which the Dutch landed in the Colony. On the sunspot theory we should expect to find the weather of that year similar to that of 1885. The following extract is taken from the hand-book of the Colony prepared for the present Colonial and Indian Exhibition.

"The winter of 1652, from July to August was an exceptionally severe one; part of Table Mountain was white

EASTERN RAINFALL—CAPE COLONY.

TABLE SHOWING THE DISCREPANCY BETWEEN THE CALCULATED AND ACTUAL YEARS REMARKABLE RAINFALL.

Remarkable Rains.	CALCULATED ON THE 11·11 YEARS SUNSPOT PERIOD.			CALCULATED ON OBSERVED MAXIMUM OF SUNSPOTS.		
	2 years retardation	*3 years retardation*	*4 years retardation*	*2 yrs. retardation.*	*3 yrs. retardation.*	*4 yrs. retardation.*
1821-22	Discrepancy of 4 years	Discrepanc 3 years	Discrepancy of 2 years	Discrepancy of 3 years	Discrepancy of 2 years	Discrepancy of 1 year
1828	,, 0 years	,, 1 year	,, 2 years	,, 2 years	,, 3 years	,, 4 years
1841-42	, 1 year	,, 0 years	,, 0 years	,, 2 years	,, 1 year	,, 0 years
1848	,, 3 years	,, 4 years	,, 5 years	,, 2 years	,, 3 years	,, 4 years
1862-63	,, 0 years	,, 0 years	,, 1 year	,, 0 years	,, 0 years	,, 1 year
1874	,, 1 year	,, 0 years	,, 1 year	,, 2 years	,, 1 year	,, 0 years
1885	,, 1 year	,, 0 years	,, 1 year	,, 0 years	,, 1 year	,, 2 years
	Sum = 10 years	Sum = 8 years	Sum = 12 years	Sum = 11 years	Sum = 11 years	Sum — 12 years
	Mean $\frac{10}{7}$ = 1·43 yrs	Mean $\frac{8}{7}$ = 1·14 yrs.	Mean $\frac{12}{7}$ = 1·71 yrs	Mean $\frac{11}{7}$ = 1·57 yrs	Mean $\frac{11}{7}$ = 1·57*	Mean $\frac{12}{7}$ = 1·71 yrs

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* Since the 1885 rain fell during the last quarter of the year the figure 1·57 may be reduced to 1·46 and the mean figure for the previous column may for the same reason be raised to 1·60.

with snow, *and so much rain fell that the land resembled a sea.* There was much sickness, and several deaths among the garrison. But all the privations and discomfort of these months were forgotten, with the advent of the Cape spring in September, when the verdure of the hills and the valleys afforded pleasure to the eye."

Thus one might be tempted to remark that sunspots came to this country with the Dutch!

Since the discovery of sunspots and of the connection between their periodicity and earthly magnetism, astronomy has entered on a new path. It is no longer the abstruse study of star movements. With the recent discoveries of physical astronomy the dry bones of the old science have become clothed with new life. Man has never armed himself with a more wondrous instrument than the spectroscope. With it our feeble senses are able to grope their way to a knowledge of what is going on at an eternity of distance in the great Sun, from whose stupendous energy we draw all our force and all the life that throbs on this earth. Not only can we watch sunspots, prominences, and other changes in the sun, but we know when to expect them. Any variation in the sun's power influences the climate of our earth; it influences it directly in those parts of our globe—equatorial regions turned towards the sun; indirectly in those turned away from the sun. It behoves us therefore, in this sunny land, removed but 33° from the equator, to neglect no opportunity of studying how far our periodical changes of climate are effected by the Mighty Power enthroned in the skies.

* * *

OUR CLIMATE

AND ITS

VARIATION IN CYCLES.

DELIVERED

BEFORE THE LECTURE COMMITTEE,

GRAHAMSTOWN EXHIBITION,

DECEMBER 1887,

BY

D. E. HUTCHINS,

CONSERVATOR OF FORESTS, KNYSNA.

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OUR CLIMATE

AND ITS

VARIATION IN CYCLES.

PART I.—OUR CLIMATE.

I shall in this lecture offer some remarks on our climate, then on cyclical variation in climates, and finally on the variation in cycles of our climate. We know that the climate of South Africa varies in cycles, that the climates of other countries similarly placed, such as Australia, South America, and India, also vary in cycles. This cyclical variation is probably due to more causes than one. It is of so great an importance to this country, that I need not apologise for presenting you with this sketch of how the climate of South Africa has varied in the past, and how the repetition of the same cyclical variations in the future, will enable us to foretell the character of the seasons, year by year, they being mainly dependent on that variation in the sun's power of which sunspots are the most convenient index.

Let us first consider how South Africa is placed with reference to the climates of the world. Above us, to the north, is the great tropical continent, with its regular tropical climate, having all its elements directly governed and closely following the all-powerful sun. Below us, to the south, is the great waste of waters with no continents to alter or deflect the two great air currents of the trade wind and the anti-trade wind. No visitor to the tropics, who observes the weather can fail to be struck with the even regularity of a tropical climate. To one accustomed to the barometer of temperate climates, it is amazing to watch the instrument in the tropics moving up and down like a well-regulated clock. I had in

Southern India a sensitive aneroid by which I could tell the time of the day within a quarter of an hour. When it is borne in mind that the barometer is the exact index of the pressure of air above us, that the air can not be colder, warmer, wetter, drier, denser, or rarer, without sending the barometer up or down; it will be realised how extraordinary is the regular barometer of the tropics. In the tropics the fickle wind does not blow where it listeth; it blows where the all-mighty sun uplifts it. The ever varying systems of cyclones in temperate climes are absent in the tropics. In India the monsoons are unchanging winds that blow from the same point on almost the same day every year. On the Western coast of India where the advent of the S.W. monsoon makes a complete change in the habits and occupations of daily life they have an official commencement of the monsoon. Punctually, usually within a few hours, the real monsoon arrives—" breaks " as it is termed by Anglo-Indians. The breaking of the monsoon on the Western Ghauts of India is an experience one does not easily forget. The inky sky is ablaze with lightning, the thunder claps run into one continuous roar, and the rain descends in torrents. In 1883, eleven inches of rain fell in the first 12 hours after the monsoon broke. To one living alone in the forest such a scene forcibly recalls Livingstone's description of the setting in of the rains in tropical Africa. In tropical India there is an early and a latter rain, the sun as it moves north drawing the rain-clouds in its wake. In tropical Africa there is an early and a latter rain following the course of the sun in the same way, but in Africa the latter rain is the greater. These are the seasons, Livingstone tells us, all over South Tropical Africa; as the sun passes overhead on its journey South the rain-clouds follow; and the spring rains break-up the winter drought. As the sun returns overhead on its journey back to the Equator, it brings the heavy autumn rains. These Tropical rains extend right down the eastern coast of South Africa, and with some storms from the south-west constitute the summer rains of this side of the Colony. Somerset East and Grahamstown mark the western limits of the heavy tropical summer rains, and there is here a dividing line of great importance. To the east is fertile South Africa, corresponding to the fertile portion of south-east Australia. To the west of this line is the region of the Cape proper, amazingly fertile at first sight with the splendid winter rains of the temperate zone. This fertility is, however, little more than a hollow shell. The Cape region proper may be described as a desert with a narrow strip of fertile coast crowned with the beautiful oasis of the Cape Peninsula, In old maps of Australia you will see " Australia felix " written across the fertile south-east portion. In West Australia lie the deserts with a narrow strip of fertile country round the coast. The similarity between the climates of the southern portions of Australia and of Africa can be followed into greater detail ; the same winds bring the same rains, at the same time and place on both Continents. With this similarity there is the difference that while the African Continent shrinks away at its fertile south east extremity that of Australia swells out and affords room for the colonies of Victoria and New South Wales. But against this we have the sett off that while in the interior, Australia sinks into burning plains, South Africa rises to cool fertile plateaux and gives room for the Transvaal. It must not be forgotton that a small portion of Australia lies south of the latitude of Cape Colony. This, with its winter rains, is fertile like the Cape Peninsula and the strip along the southern and western coasts of Cape Colony.

With its last annual report the Meteorological Commission published a series of rainfall charts reduced from maps compiled by the late Hydraulic Engineer, Mr. J. G. Gamble. These maps are very instructive. The annual map here shown has been prepared from the maps of the Meteorological Commission, and coloured to show the rainfall division of South Africa into desert, karoo, and fertile country. In the monthly maps, one sees at a glance the incidence, month by month, of the all important rainfall. We see how insignificant are the winter rains. They bring two patches of heavy rainfall; to the Cape Peninsula and to the Knysna forest country ; they water with a moderate rainfall the narrow strip of fertile coast, but the bulk of the country is left untouched, Look on the other hand at the summer tropical rainfall: it covers the eastern side of Cape Colony, the Transkei, Natal, and the greater portion of the Transvaal and the Free State with a sufficient rainfall. Reinforced by storms from the Southern Ocean, it brings probably the heaviest rainfall in Cape Colony to the forest country, on the Amatola-Katberg Range and its continuation across the Kei River. These maps are on too small a scale, and the number of rain-guage stations are too few to enter into details. For the south-eastern districts it may be stated that the yearly rainfall between Queenstown and the sea varies between 20″ and 30″, and that on the forest clad mountain ranges running midway across these districts the rainfall rises to nearly double these figures. The Forest Department maintains 10 rain-guage stations, at selected points on the Perie, the Amatola, and the Katberg ranges. These ten forest guages yield higher figures than any similar group of stations elsewhere in the Colony.

To my mind, it is mainly to climate, that we owe the rapid development of the southern portion of Australia and the slow development of South Africa. The Australian Colonies started in "Australia felix," and the rapid occupation of the fertile lands followed as a consequence. South Africa began colonisation at the wrong end. What would be said of Australia with its capitrl and its centre of civilisation at Perth! And yet from a climatic point of view this is the position of matters now in South Africa. Possibly this may always be so. As colonisation in South Africa approaches the fertile eastern side of the continent, it is thrown back by the barriers of native populations, artificially fostered and protected. The Spanish Missionaries in California introduced a quasi-civilization among the Indians which lasted for more than a century, until the gold discoveries colonised the country with a rush. An influence such as the discovery of the Transvaal Gold-fields which tends to bring money, wealth and intelligence into fertile South Africa,as did the Gold-fields in Australia, is far more likely to be of lasting benefit to the country than the finding of diamonds in the desert, and the founding of a town which will be abandoned when the diamonds are worked out. If statesmen were all meteorologists they would be saved from some of their worst blunders!

The area covered by the tropical rains in South Africa marks the limits of what is known as the tropical flora, in contradistinction to the Cape flora proper, characterising the country covered by the western winter rains. The eastern forest country with its cold climate and not absolutely dry winters. falls into a sub-division of the tropical flora on the one side and the coast sub-tropical flora on the other side. This subject is ably discussed in a paper in the Cape Handbook by Mr. H. Bolus, the botanist The way in which some of our forest species follow the rainfall into the cold temperate climate of our eastern mountains is worth noting. The Sneezewood (*Pteroxylon utile*), and the Cape Chesnut (*Calodendron Capense*) are sub-tropical and tropical species which, in the Amatola forests, are found growing at elevations with a mean temperature little above that of London. In their tropical homes both these species are evergreen; but in cold situations they shed their leaves in winter, the Cape Chesnut so much so, that in our forests nurseries it is handled like an oak. Livingstone and other travellers in the interior speak of the tropical rainfall as coming in two periods of which the latter is greater than the former. These characteristics re-appear in the eastern rainfall of Cape Colony. Our heavy eastern rainfall is in spring and autumn the latter being the heavier. And in bad seasons there is often a short sharp drought towards midsummer. Again, in autumn and early winter in the south-east of Cape Colony, the winds from the north are moderate. and mild in temperature; but as the winter drought becomes more severe in the interior we get that mixture of violent hot and cold winds, all parchingly dry, which are such an unpleasant feature of winter and spring in the east of Cape Colony. It is a comforting reflection in spring that as the sun creeps towards us and these winds become hotter and more unpleasant, behind the sun trail the rain-clouds, blessed with moisture and mild weather.

Sometimes they do not get rains in the Free State until Christmas, and then it will be easily imagined how hot and unpleasant are winds from that quarter to us dwellers below the plateaux. Here perhaps it should be mentioned that a wind descending from a heated plateau becomes more hot and parching for the inverse reason that a wind blowing up a mountain side becomes cool and practically moist. In this way, dry air gains 1° Fah. for each 183 feet of descent. For ordinary moist air not descending abruptly the gain is 1° Fah. for each 300 feet. Air descending undiluted from an upper region to a lower one of greater pressure is compressed and gives out sensible heat exactly as when in a lecture on physics we see that air compressed by an air pump becomes hot. In this fact, lies the difference between the climates of Grahamstown and King Williamstown, the mildness of the hot winds in the former, their unhappy intensity in the latter. The difference of the two places in elevation above sea-level is not enough to produce a difference of one degree Fahrenheit, but the secret lies in the surroundings. Grahamstown occupies a commanding position dominated by no mountains, or worse still by plateaux. King Williamstown is dominated by the Perie and Amatola Mountain Ranges, each of which are but steps on to bare tree-less plateaux above. The wind from these plateaux constitutes the hot winds of King Williamstown. There is a valley below the Andes, in Peru, where, for the same reason, the air is so parchingly dry that neither man nor beast can long endure it, and corpses are mumified (as we make biltong) by the simple process of hanging them out to dry. It has been remarked, somewhat unfeelingly, that towards the end of summer in King Williamstown some of us look as if we had been hung out to dry! As showing how the hot winds of King Williamstown are caused mainly by the descent of warm air from the plateaux above, it may be mentioned, that when a hot north wind is blowing in winter or spring, it is more felt at the base of the Amatola or Perie Mountains than in King Williamstown itself which stands some way out on the plain, and thus receives the hot wind somewhat diluted by cool air from the coast.

We have seen that our Eastern rainfall is tropical in character and that our hot winds depend to a great extend on the fall of rain to the north of us, we must now glance briefly at our winds and how they come to bring us rain. Omitting details, what happens broadly is this. Near the Equator, immediately under the sun, is a region of calm and variable winds. Here the sun is at its maximum power, and the air in contact with the heated earth is ever becoming warmer, rising and flowing off on both sides towards the poles. Endowed with the greater volocity of the earth at the Equator, as the warm air moves towards the poles, it curves naturally towards the west. This is our North-west Anti-trade wind. Nearer the poles it curves still more to the west, and blows nearly due west round high southern latitudes. In New Zealand the prevailing wind is westerly throughout the year—north-west in winter, south-west in summer. Very little is known, from direct experiment, of the extent and power of the north-west anti-trade in the Southern Hemisphere. In the Northern Hemisphere the corresponding south-west equatorial current is deflected by continents, but its existence as a general upper current is demonstrated by baloon ascents and observations on mountain peaks. In the Southern Hemisphere where there is but one small continent and the tails of two continents, the winds have uninterrupted play, but much less has been done in observing them. All facts, however, point to the more or less continuous existence of an upper anti-trade current, and the descent of this current and its re-appearance at sea level in latitudes South of Cape Colony.

From a study of our weather I have come to the conclusion that the prevailing upper current of the atmosphere in Cape Colony is the North-west wind. Dr. Meldrum's charts show that our storms travel eastwards with surprising regularity: ask anyone who has observed the weather in Cape Colony and he will point to the north-west as the storm quarter. Cirrus clouds—the clouds of the upper atmosphere, may usually be observed pointing from a westerly or north-westerly direction. As we ascend the mountains the dry keen north-west wind becomes more strikingly predominant. I have figures from some of the forest rain-guages which show that the rainfall diminishes from 4,000 feet to 6,000 feet elevation in a vertical plane. On the Amatolas the upper limit of forest vegetation is at about 4,000 feet elevation. Everywhere on the mountains it is the north-west wind which overturns the trees ; and it is the south-east wind that blows the trees down near the coast. Daily weather reports (for which I am indebted to the Meteorological Commission) show that frequently while furious south-east winds are raging along the coast it is calm on the mountain tops ; or *vice versa*, there may be a furious nor'-wester blowing on the mountains while it is calm along the coast. In fact the south-east wind which everyone knows as a power along the coast may be said to be scarcely existent on the mountains. We shelter our forest nurseries and look out for our buildings to the north-west, but are indifferent to wind from other quarters. Under certain conditions of the atmosphere we can see this upper north-west current with our own eyes. My forest duties sometimes take me high up into the mountains. More than once, during lulls in the drenching rain of a south-east drizzle, I have looked through the parted clouds into a blue sky across which the fleecy clouds of the upper atmosphere were drifting gently from the north-west. As a local phenomenon I have at Port Elizabeth seen what resembled a south-east cross current above light mists and drizzle from the north-west, but I have never looked through a genuiue north-west storm and seen an upper south-east current. It may be objected that this is negative evidence. But, taken with other facts, it has always appeared to me that this looking through the rift in the clouds was a glimpse behind the scenes at our weather, the two main features of which are an upper dry current from the north-west, and a lower moist current from the south-east. The south-east trade wind in a broad sense is the return current blowing from the south to supply the place of the air drawn upward by solar energy at the equator. It is the low level wind that mariners meet every where between the equator and about our latitude. Looking to the situation of Cape Colony on the map you will see that as regards surface winds, to the north of us lies the region of the south-east trade, to the south of us the region of the north-west anti-trade wind. The boundaries of these two regions shift north and south with the position of the sun. Thus in summer the south-east trade is the prevailing wind in Cape Colony, while in winter the north-west anti-trade, the "roaring forties," is the prevailing wind.

In summer the S.E. trade wind, blowing directly off the ocean comes loaded with moisture and brings the tropical rain we have been speaking of above to the eastern side of the continent. It is easy to imagine how as the sun moves south in summer till it stands almost vertical over Cape Colony, the heated air rises and lets in the cool, moist trade wind with increased vigour.

In winter different conditions prevail; the sun has little heating power; it is away to the north shining over Europe; the north-west anti-trade then blows over Cape Colony, as it usually blows in latitudes more to the south, and the character of our storms resembles those of higher latitudes.

Of storms, it would be taking us too much into details to speak to-day. The great interest attaching to their study lies in the fact that certain laws govern their rotation and movements; and that knowing these laws when one has made out what atmospheric movement is in progress, one can foresee what weather is coming. And more than this, one can be warned by telegraph of the approach of storms. Especially can this be done on the eastern side of the Colony, as our storms, like most others, travel in an easterly direction, coming usually from the west in winter and south-west in summer. In winter the northern side of cyclonic storms are best developed; in summer the southern side, rain beginning with a south-west wind and lasting till the wind has veered through south and south-east to east. To attempt to discuss storms, cyclones, and anti-cyclones, would introduce details which, as I have said, have no immediate bearing on the subject of this lecture: they effect the weather from day to day, but not its cyclical variation. What I have endeavoured to place before you so far as we have gone, is our tropical rainfall; and, the intimate dependence on the sun of our two great systems of wind circulation from the south-east and from the north-west.

THE AGULHAS CURRENT.

An ocean current, the Agulhas current, has a most powerful influence on the climate of South Africa. It may be looked upon as caused by the south-east trade wind, and as the backwash of the waters flowing from the south to supply the great loss by evaporation in the Indian Ocean. The south-east trade wind accelerates the velocity of the current most in summer. It sometimes runs past Durban with a velocity of four miles per hour and is traceable as far west as Cape Point, whence its place is taken by the cold arctic current, that modifies so beneficially, the climate of the Cape peninsula. The influence of the Agulhas current is apparent in the high mean temperature of East London, and the semi-tropical character of the vegetation of the Transkeian coast, rendering that coast region unsuitable for healthy European colonization. Happily, west of Port Elizabeth, the Agulhas current becomes less of an evil, cold southerly currents modify its temperature and frequently creep in between it and the coast. This mixing of the ocean currents, and the proximity of the Outeniqua mountains,bring about that great change in the climate and vegetation which we see in passing into the Knysna forest region, with its beautiful flora,belonging to the Cape region proper. The climatic change is intensified by the presence of large areas of high timber forest—forest where the size and growth of the trees are surpassed only by the best wooded portions of the Amatolas.

LINE OF HEALTH.

As a result, partly of the Agulhas current and partly of the loss of latitude, we see, in going from Cape Town to Natal, that there is, for South Africa, a sufficiently well-marked altitude *line of health.* This line of health may be taken to lie roughly at about 3,000 ft. for Natal, 2,000 ft. for the Eastern Coast of Cape Colony, 1,000 ft. for the Southern Coast where the Agulhas current is much mixed with cold counter currents; and, south of Cape Town, under the influence of the cold Arctic current, the line of health may be said to sink to sea level.

Above this line of health we see white colonists with nearly the health and vigour characteristic of country people in north-western and central Europe, and with a physique far superior to our fellow countrymen living in large towns in England. Below this line of health, the evidences are unmistakeable, to a practised eye, that for people of pure north European race, the climate is too hot. For consumptives, for invalides, and for people constitutionally adapted to a warm country, the soft air of the south-eastern coast has its advantages, but for the strong it means a gradual physical and moral degeneracy.

In similar latitudes, on the north side of Africa, we see the Kabyls, a fair race of Keltic origin, inhabiting the mountains of Algeria, while the hot lowlands are peopled by Arabs. This is an extreme case, the Algerian summer being far more trying to Europeans than that of South Africa; but, this may be said, that if every one were in their right places in South Africa, where they could lead the happiest and best lives, we should see people of North European race living above the imaginary line of health I have sketched, and below this line ,mixed races; or, what would be infinitely better, colonists such as Italians from the south of Europe.

RAINFALL.

These considerations will help us to understand why, in a broad sense, the western half of South Africa is sterile or nearly rainless; the eastern half, fertile and blessed with a sufficient rainfall for grass and most agricultural operations. In winter the prevailing winds are westerly. A narrow strip of country along the western and southern coast has the good winter rains of the temperate zone. But these rains do not penetrate far inland. The rains from the Indian Ocean on the contrary find their way apparently right across the continent to Bechuanaland and even, in summer thunderstorms, to Namaqualand. It is certain that the whole of the rainfall coming to the Portugese possessions, the Transvaal, the Free State, Natal, and the Transkei comes from the Indian Ocean. Nearly the whole of the eastern rainfall in Cape Colony comes also from the

Indian Ocean. This enormous difference between the Atlantic and Indian Ocean rainfalls seems to be due primarily to the temperatures of their waters. The prevailing winds are from the Indian Ocean in summer, from the Atlantic in winter. Let us look at the conditions prevailing over each ocean when the winds are favourable for rain. Over the Atlantic the feeble evaporating power of the sun in winter is still further lessened by local rains and storms and the low temperature of the water. Icebergs have been reported within a day's sail of Cape Town. The cold high-lying plateau of the Karroo and the country to the north are rainless and *cloudless* in winter with winds blowing steadily off the Atlantic Ocean. The small evaporation from the cold Atlantic water has spent itself in the narrow belt of coast rain. Now glance at the Indian Ocean in summer. The warm water sweeps down from tropical latitudes ; across it blows the trade wind with a steadiness that is almost proverbial, and that caused the old Spanish navigators to term it the "ladies' wind." The sun shines brightly over the sparkling waves, but this sun is nearly or quite vertical, and evaporation is going on with tropical intensity. Tremendous masses of vapour pass over the heated land, unnoticed save that here and there a mountain top is girt with mist like the mountain tops that pierce the monsoon currents in India. A chain of mountains, barometric depressions, local thunderstorms, displace the vapour currents and bring down those heavy summer rains with which we are familiar. In 1887 the highest rainfall registered in Cape Colony was furnished by stations in the Amatolas mountains which, from their situation, are the first to displace the vapour currents from the Indian Ocean. The mean rainfall at two forest stations in the mountains north of King Williamstown was 77·88 inches. The summer rains of South Africa in their origin and volume are similar to the monsoon rains of India.

VEERING OF THE WIND.

I have now to allude to an important point of every-day weather lore, of which I shall speak in theory and practice. You may not all carry away the theory, but the practice is of every-day use; and, as will be shown, the trees around us on every side—the trees of which Grahamstown is so proud—stand as mute but never-failing witnesses. These trees bear witness to the veering of the wind. A wind is said to veer when its changes of direction follow the apparent motion of the sun. Thus, with us in the southern hemisphere, a wind "veers" from east to north from north to west and so on. When a wind changes its direction against the apparent motion of the sun it is said to "back," thus, the wind backs from north to east, from east to south, and so on. In Cape Colony our winds rarely back, and the regularity with which they veer is *the most important point* in our meteorology for every-day folk. It is of practical use to every one; because, if one can predict what way the wind will shift, it is not difficult to make a forecast of the weather.

A curious fact in connection with this veering of the wind has recently come under my observation. Most people are aware of the defect, so common to Blue-gums in South Africa, of having a twisted trunk. It is for this reason mainly, that the Blue-gum, in Cape Town and elsewhere, is used only for firewood. A straight plank, that will season straight, cannot be cut out of a twisted trunk. I have seen the trunks of Blue-gums twisted through an entire circle and sometimes through two circles. Everywhere in Cape Colony Blue-gum trees twist uniformly in one direction—contra clockwise, according to the veer of the wind. The twisted trunk is more marked in Blue-gums than in other trees, on account of their stature and rapid growth, but the peculiarity is not confined to Blue-gums. Other kinds of gums and pines show the same tendency to twist. Occasionally the tall Yellow-woods in the forest are seen twisted quite as badly as Blue-gums. On the other hand, in southern India where the Blue-gum is exposed to the mighty blasts of the south-west monsoon, but where there is no tendency of the wind to veer in one way, the Blue-gums are not twisted to any remarkable extent. Neither in our Colonial Blue-gum plantation at Worcester where the trees are grown close are they twisted to the same extent as trees grown unsheltered. The tall trunks and massive crowns of both Yellow-wood and Blue-gum trees render them peculiarly sensitive to the torsion of a veering wind. The former growing in the forest and the latter in the open would account for the former being more rarely seen twisted than the latter. Of course it is possible that some other cause may have to do with the twisting of the Blue gum. But the veering of the wind alone seems quite sufficient to account for the appearances. I have more than once noticed a single branch of a Blue gum bent and twisted by the wind round its own trunk. The fact that a branch of a Blue-gum tree is sometimes twisted on its own axis, must be set down to inherited tendency ; the Blue-gum being a native of Australia where the wind veers as in Cape Colony. The twisting effect of a veering wind on a yielding elastic body like the crown of a tree, can easily be shown in a diagram. Forest trees may occasionally be observed twisted in a direction contrary to the veer of the wind ; but this is rare. Blue-gums growing in the open freely exposed to the wind, always twist with the veer of the wind.

If any one should forget which way the wind veers in Cape Colony, he, or she, has only to step out of doors and look at the first gumtree. If the wind is blowing from the West for instance, the chances are that it will veer towards the South, and bring rain, damp, cool, or cold weather. Thence the wind will tend to veer through East to North-east, when it will bring hot dry weather. So far for the practical part of the subject.

To consider now the reason why the wind *veers* so much more commonly than *backs*.

In Cape Colony there are two reasons for the veering of the wind, the first reason general, the second local. On account of the rotation of the earth, every wind in the Southern Hemisphere except one blowing due East and West, tends to curve to the left The general truth of this, a few minutes reflection will show is obvious. An exact statement of the law was first made by a meteorologist, named Ferrel, and hence this is known as Ferrel's Law. In obedience to this law, a burst of the N.W. anti-trade tends to veer to the west and die out. In practice this is often noticeable. For the same reason a burst of the south-east trade wind will veer to the east and north-east, and die out with one, or as often two, hot days. Sometimes the wind will veer in this way from north-west round to south-west, and then from south-east round again to north-east with all the appearances of a well developed cyclonic storm. I have in my hand a Barograph tracing on which the winds have been entered, showing such a circulation of the wind on the 7th, 8th, and 9th of this month (December 1887). The barometer, however, shows that these winds are in no true sense cyclonic but simply accessions of the two great air currents of our atmosphere, comparable, in their coming and going, to what are known in India, as bursts of the monsoon. In accordance with Ferrel's law, such bursts of the monsoon blow near the Equator in simple intermissions without any veering. It was as such that I knew them at Madras. In the latitude of Calcutta just within the tropic the veering of the wind can only be detected with the aid of instruments. Says Mr. Blandford, the head of the Indian Meteorological Department, " A discussion of the anemometric registers of Calcutta for fifteen months shews that, while the wind vane had made nine complete revolutions in the direction north, west, south, east, north, it made thirty-four in the opposite, i.e. the normal direction." Ferrel's Law which is of increasing importance as we go from the Equator to the Poles is then the first reason for the veering of our winds in Cape Colony.

The second and local reason is that the usual track of our storms or wind movements, cyclonic and anti-cyclonic, is up the Agulhas current. As they move off eastward towards Australia, Cape Colony gets the benefit of the northern half of the wind circulation, cyclones with the wind circulating clockwise and anti-cyclones with the wind circulating contra-clockwise. If you will consider for a moment the local veering of such a wind circulation, you will see that it is always for Cape Colony in one direction, viz., contra clockwise, or with the sun. With a wind changing in the opposite direction, or more strictly speaking " backing," a meteorologist would look out for a depression passing across, from west to east, northward of the observer. In Cape Town and the south-west this sometimes happens. On the eastern side of Cape Colony it is very rare. I have only noticed it in February, the heated land surface to the north of us accounting for it then. But generally, in Cape Colony, a backing wind is extremely rare, and it is a safe rule to observe that, if you want to know how the wind will shift at any time, look at the trees and they will very rarely be false prophets.

The Hon. Ralph Abercromby, to whom we are indebted for valuable observations, on the veering of the wind, and cloud movements in the upper atmosphere, has ascertained this law. In the Southern Hemisphere, the upper winds blow across the surface wind, coming, as we ascend, from a direction more and more to the right, supposing the observer is standing with his back to the wind. This screw-like wind circulation is possibly nothing more than the general veering of the wind retarded by friction at the surface of the earth. My own meteorological notes and recollections fully confirm Abercromby's observations.

Before quitting the subject of our winds, there are two constant local wind effects to be mentioned, which if left out may lead to misapprehension. I allude to (1) calm nights; (2) the morning and evening land and sea breezes. The latter occur regularly, in all clear sun-lit countries. They are due to the fact that, the sun heats the land more than the sea during the day, and the warm air of the land rising is displaced by cool heavy air flowing in from the sea—the sea breeze. In the city of Madras with its mean temperature of 82° Fah. existence would be hardly endurable for Europeans without the sea breeze. On clear nights the land cools faster by radiation and then the reverse process happens. In tropical countries generally, the enervating coast would be scarcely bearable but for the strong breeze which blows cool, in the evening off the sea and in the morning off the land. In Cape Colony the land and sea breezes are most felt along the coast and along the highlands facing the sea They appear at places such as Queenstown, where there is the dry sun-lit Karoo on one side, and a moist region and the sea on the other side. The tendancy to land and sea breezes is almost universal in Cape Colony. This daily tendancy will check or reinforce, as the case may be, the wind movements then in progress, and hence must never be lost sight of. The sea-breeze is always more powerful than the land breeze and in Cape Colony markedly so.

The normal clear calm night of hot countries has been everywhere described by poets and vouched for by travellers. The breeze that precedes the dawn is the coldest time round the Canadian camp fire. Camping in our forests a whispering breeze in the tree tops often precedes the twitter of the birds and the blush of dawn in the east. As the sun rises the powers of the air shake themselves free. No weather saw is truer than the remark, that if you wish to see how the day will turn out, wait till an hour after sunrise. In my experience, calm nights are even more characteristic of temperate sun-lit countries such as Cape Colony, than of hot countries like India. The following explanation accounts for this. In the clear atmosphere of South Africa, the sun is all powerful by day and radiation by night. The atmosphere by day is, as it were, a billowy mass of hot ascending currents and cool descending currents. We at the bottom layer of the atmosphere are thus kept in touch with the strong unimpeded currents of the upper atmosphere. At night the opposite occurs. Radiation cools the earth, and the earth the lowest atmospheric stratum resting on it. The colder it gets, the more heavy and still lies this low layer. Its coldest and lowest portion slowly gravitates into hollows and causes night frosts. As a mass, it lies still and unbroken, till the morning sun sets it dancing and streaming off into the upper atmosphere. Looking over the plains of Kaffraria from the Amatola Monntains on moonlight nights, or early in the morning, the position of the stratus cloud(the night cloud) shows very clearly what I have been describing. It fills up the hollows and flecks the plain with white patches that do not alter their position from hour to hour. I am very familiar with the same appearance over the plains of Mysore in India seen from the Peak of Nundidroog (4,840 feet). If any corroboration of this observation were needed, there is the fact that night winds are less rare on mountains than at low elevations. This I have noticed both in India and South Africa. On the Amatolas at 4,000 or 5,000 feet elevation, still nights are far from being as common as on the plain. The same thing occurs on the Onteniqua Mountains: night winds are less rare at Millwood (1,500 feet) than at Knysna (sea level). Of course, when any powerful movement of the atmosphere is in progress the cold night stratum is swept off like chaff. It is nevertheless astonishing, what strong winds will sink to light breezes or to a dead calm during the night, reappearing again in full strength the next day, a few hours after the sun has appeared and heated the earth. If you are following the progress of a storm or other wind movement, the temporary night lull during clear weather has no general significance. An hour or two after sunrise you will find that the wind movement has advanced a stage while you and nature have been asleep under the cold still air canopy of night.

Of course, local winds, which are mainly influenced by the sun, start into activity in the morning as soon as the rising sun has made its influence felt.

The night lull is most remarkable in summer, and during bursts of the South-east trade. This with the above explanation, is easily accounted for, and likewise the fact that at sea where radiation is less, the night lull is less noticeable.

RECAPITULATION.

Before closing this sketch of the more prominent features of our climate, it may be well to recapitulate a few central facts.

Nine-tenths of the rain-fall of South Africa is from or on the Eastern side. This rain-fall visits us in summer; it has tropical characteristics and the bulk of it comes from the Indian Ocean and the waters to the South.

Our winds are of two kinds, fixed winds and variable winds. The fixed winds form part of two great atmospheric currents, termed the North-west Anti-trade and the South-east Trade wind.

The variable winds blow from any direction, but usually form part of storms which whether violent or not, belong to two types termed cyclones and anti-cyclones

A cyclone is an area of low pressure in which the winds circulate clockwise and inwards.

An anti-cyclone is an area of high pressure in which the winds circulate anti-clockwise and outwards.

All these weather movements, whether cyclones or anti-cyclones, advance on us from the westward and the North-west Anti-trade seems to be the seat of most of our changes of weather. In this part of Cape Colony the wind always tends to veer contra clockwise. This tendency is due to the operation of a universal law known as Ferrel's law; and to the fact that weather movements whether cyclonic o anti-cyclonic, if following the common track, pass away to the eastward with their centres to the south of us. The greater portion of the storms of South Africa pass up the Agulhas current. They can often be traced from Cape Town to Durban.

PART II.—CYCLICAL VARIATION.

Having presented you with this sketch of our climate, its winds and rainfall, we come now to the second part of this lecture, the variation of our climate in cycles. That the climate of this and other countries does vary in cycles is a truism to most people here to-day. Meteorologists have studied the subject under a variety of aspects ; the cyclical variation for different countries of temperature, of rainfall, of wind disturbances, of magnetic phenomena, etc.: and they have followed the subject up into various branches, such as heights of rivers and lakes, and prices of food-grains, where these depend on rainfall. Mr. Proctor, the astronomer, thinks he has found a small annual rise and fall of temperature dependent upon the earth's path in space having to traverse meteor streams. Then there is the popular monthly variation of climate depending on changes of the moon : another possible variation with a period of 25 days depending on the sun's rotation. Of local importance is the tendency to a recurrence of certain weather at certain times. Nothing, however, as regards cyclical variation has been discovered, of any general interest, except the variation in the sun's power, which rises and falls with the appearance and disappearance of sunspots and other markings on the sun's face.

Rather more than a year ago, I gave a lecture in King William's Town on sun-spot influences, which was reprinted in a Grahamstown paper, and partially repeated in a lecture at Kei Road a few months afterwards This has aroused interest in the subject, and brought forward objections, which I shall endeavour to-day to answer. In doing this, I shall at first quote independent authorities and then give you opinions and conclusions of my own This is how the subject is cautiously stated by Mr. Blandford, the head of the Indian Meteorological Department:—"Solar radiation which is the source of all atmospheric energy, is apparantly subject to variation ; the activity of the Meteorological changes of our atmosphere must therefore vary in like manner. Sir W. Herschel, at the beginning of the present century, attempted to show from the very imperfect records at his command, that years of remarkably abundant or deficient spots have been also remarked for their high or low general temperature, and especially for abundant or deficient harvests." You will see presently that since Herschel's time very little has been done either to study the cyclical variation of climate at the Cape, or to bring the cycles into harmony with the recent advances in solar physics. A disturbing influence has affected, more and more, that general connection between sunspots and rainfall which, in Herschel's time was sufficiently strong, until at last, the subject has been almost abandoned by meteorologists.

The main facts in my King William's Town lecture were these:—In tropical climates the rains are caused directly by the sun. The sun is more powerful during years when it has more spots, the spots being signs of solar activity. Thus, in years when there are most spots the sun evaporates most from the ocean, and there is most rain in tropical countries. At more than one Station in South India, but most notably at Madras, where the rainfall observations have been long and carefully taken, there is a remarkable correspondence between rainfall and sunspots. Taking average figures, over a long term of years, max. rainfall corresponds with max. sunspots. The curves on this lecture-diagram are plotted from the sunspot and rainfall figures, and show at a glance how the two run together. The difference between the blue curved line, and the straight dotted line shows the sunspot influence.

At Bombay, sunspot influence is less well marked in the rain-guage figures; and further north the correspondence ceases. Indeed it appears that the rain-clouds drifting unbroken over the heated plains of the South bring rather more rain to Northern India in years of minimum sunspots. The same thing occurs with the Karoo rainfall of S. Africa This is worth noting because it is a plansible objection often brought against sunspot influence, that the sun acting all over the earth must bring droughts and rains at the same time everywhere. The fallacy of this reasoning is of course in the assumption that variation in solar energy has the same meteorological influence all over the earth.

The strongest evidence of the connection between sunspots and seasons in South India, does not come from the too often untrustworthy evidence of rainguage figures, but from the unfailing index of the prices of food grains. Until quite recently India was a world in itself. It exported little grain, and imported none. There were few roads and little intercommunication between different provinces. The bulk of its inhabitants were, and are still, small agriculturists. When the rainfall was scanty over any considerable tract, the crops were scanty and prices of food grains rose.

When the rains failed over any considerable area famine and famine prices, followed. This is the record of famine in Madras during the century :—

FAMINE AND SUNSPOTS IN MADRAS.

(a) First years of minimum sunspots. YEARS OF FAMINE.

1810.—A famine at the exact minimum period.
1821.—A famine in 1823.
1832.—A famine at the exact minimum period.
1843.—No notoriour famine.
1854.—A famine in 1853, the drought lasting till 1855.
1865-66.—A famine at the exact minimum period.
1876-77.—A famine at the exact minimum period.

For the Mysore province in South India I published a series of figures (in 1882 in the "Madras Mail") which showed a remarkably close correspondence between sunspots and average prices of food grains in that country. Again quoting Mr. Blanford. "In Ceylon the Cyclical variation of the rainfall and of cereal abundance appears from the evidence of Mr. Ferguson, the Editor of the "Ceylon Observer," and also of Mr. Archer, a correspondent of the same paper, to be sufficiently obvious to have become a subject of popular observation ; and Dr. W.W. Hunter has contributed some facts on the authority

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(a) The minimum year, here quoted, is the first of the three min. years in each cycle.

of Mr. Robinson, which show that in Southern India, there is a marked tendency to the recurrence of periods of sarcity about the time of minimum sunspots."

But the most complete evidence of the correspondence between sunspots and food grain prices in India, has come recently from the pen of Mr. Chambers, the Government Astronomer at Bombay. Those who would care to read his admirable paper on the subject, will find it in last year's file of "Nature," June 2nd. 1886 (in the King William's Town but not in the Grahamstown Library). This paper works out the correspondence between sunspots and food grain prices for ten different stations in India. Mr Chamber's figures go back to 1810—nearly the beginning of this century. The figures are put through no mathematical manipulation, such as has sometimes been done in similar calculations, with the result that they prove anything or nothing. Mr. Chambers rejects figures during the American War, as prices were then subject to influences independent of the cyclical variation of solar energy. He meets the gradual fall in the intrinsic value of the rupee by taking an average figure for each separate sunspot cycle, and expressing the variation in prices as percentages of that average. The results are represented graphically, showing the correspondence between the sunspot curve, and the food price curve. The curves from eight stations show a close correspondence with the sunspot curves : in the curves from the remaining two stations, the correspondence is less but still fairly well marked.

"These results" adds Mr. Chambers, "reveal the remarkable fact, that amid all the apparently irregular fluctuations of the yearly prices, there is in everyone of the ten districts a periodical rise and fall of prices every eleven years, corresponding to the regular variation which takes place in the number of the sunspots during the same period. They also show that in seven out of the ten districts, the range of the eleven yearly variation of prices lies between forty and fifty per cent. of the average price, and that in the remaining three districts, the range lies between twenty and thirty per cent. The ranges are greatest in those districts where scarcity and famine are most frequent, smallest in those which enjoy the greatest immunity in these respects. In Bijapur and the neighbouring districts of Belgaum and Dharwar, the highest prices occur in the (exact) year of minimum sunspots; in Madras, Poonah, and Kandesh, a year or two later; in Kanara, Kaira, and Bhawnagar, two or three years later; and in Ahmedabad three years later.

The lowest prices occur in all the districts from three to five years after the year of maximum sunspots; that is to say, three years after at the southern, four or five years after at the northern. Bijapur and Poonah are the first to show a very decided rise of prices, and this takes place in the year preceeding the year of minimum sunspots. At all the other stations a very decide rise takes place a year or two later."

Leaving India, and coming nearer home to the tropical Island of Mauritius, there is Dr. Meldrum's great discovery that the cyclones of the Indian Ocean are nearly twice as numerous in years of maximum sunspots; and that the area they cover, in maximum years, is more than four times the average of minimum years. We do not yet know quite the measure of importance that this discovery has for us in South Africa. The usual path of these tropicyclones is at first toward South Africa; they then bend to the south, and pass away to the Eastward, like other extra tropical storms. They have been traced across Madagascar to the Transvaal, and possibly we feel their influence indirectly on the East side of Cape Colony. Speaking of the general connection between sunspots and weather, we must not forget to mention the case of the West Indian hurricanes. These also are nearly twice as numerous in maximum as in minimum sunspot years.

Writing in "Nature" (Nov. '85), Mr. E. Douglas Archibald gives the following quotations. The first is from the Quarterly Journal of the Royal Meteorological Society:—

"The records showed that there appeared to be a recurrence of low water every ten years. There was lower water in 1824 and in 1835; the period 1844—5 was low especially when compared with the years immediately before and following; 1854 was remarkably low, also 1864

—5, 1874—5, and now they came to the present low period of 1884—5."

The second quotation is from the American Meteorological Journal. It refers to cold winters in Michigan, America :—

It is interesting in this connection to notice that the local reports of extremely cold winters, place them at intervals of between ten and eleven years. The winter of 1842—3 is thus shewn to have been extremely cold ; also the winter of 1853—4 ; the winter of 1863—4 noted for its terribly cold New Year ; the winter of 1874—75, when the frost penetrated into the ground at Port Huron four to six feet, there being scarcely a thaw between January 1st and the middle of March ; and lastly the winter of 1884—85, which beats the record for extreme cold during January and February."

These figures of exceptionally cold winters in America, are almost identical with those quoted above (by a different writer) of exceptionally low water in England.

They all fall within two or three years of minimum sunspot periods.

Mr. Douglas Archibald, adds :—

" The years 1821—2—3—4, 1833—4, 1844—45, 1866—7, and 1875—7, were characterised by mild winters in Europe and unusual cold in Iceland and America ; being preceeded in most cases by drought during the summers."

To this I need only add that the record has been completed by the remarkable drought of last summer in England, again at the minimum sunspot period in 1887.

It is remarkable that this connection should be traceable between sunspots and weather in England, where the direct connection between sunspots and rain-guage returns is nowhere apparent. Of course the yield of water-springs may be influenced by cyclical variation of barometric pressure ; and the ten year period of low water in English rivers comes very near the 9·5 year period of the Storm Cycle in Cape weather. The subject in England has not received the attention it deserves.

Speaking at the meeting of the Royal Meteorological Society of England on January 18th, 1887, Mr. W. Ellis, the President, observes : " Referring to the question of sympathetic relation between sunspots and magnetism and meteorology, he thought that any complete treatment of the question in its meteorological aspect seemed to require that it should be dealt with, in a more comprehensive manner than before, for which purpose observations more completely covering the surface of the globe might be necessary, the present meteorological stations being distributed over the earth in such isolated clusters.—*Nature*, January 26th, 1887." It is not proposed in this lecture to attack the complicated problem of cyclical variation in the northern hemisphere, but quotations from northern meteorologists on the subject are interesting as showing more or less marked that cyclical variation which, in the simpler meteorology of the southern hemisphere, is so clearly apparent.

The following table, on page 64, exhibits at a glance the general connection between sunspots and various phases of the weather. It is compiled from the records of the Meteorological Commission of Cape Colony, from researches made by myself, and from an article in the *19th Century* for November, 1877, of which Mr. Norman Lockyer, the astronomer, and Sir W. W. Hunter, the statician, were joint authors. In this table no account is taken of secondary cycles, and hence in the figures relating to S. Africa we see a gradual weakening of the general connection between sunspots and seasons.

VARIOUS CORRESPONDENCES.

Before coming to sunspot influence in Cape Colony, which we are in a position to examine critically, I shall place before you the results of various enquiries and stray facts which in themselves have little more than a suggestive significance, but which taken together tell strongly in favour of sunspot influence.

In weighing this secondary evidence, we are clearly entitled to look at it in this way. Suppose, for example, in ten places we find five where the meteorological phenomena correspond to the sunspot cycle, and five in

GENERAL CONNECTION BETWEEN SUNSPOTS AND WEATHER.

PARTICULARS.	Number of years observd.	Min. years.	Inter-mediate years.	Max. years.	AUTHORITIES.
SUNSPOTS	65	13	44	77	Wolf.
Famines at Madras	66	5	1	0	Hunter.
Rainfall at Madras	63	40”	49”	54”	Hunter.
Rainfall at Bombay	59	69”	72”	75”	Hunter.
Rainfall at Cape Town	28	21”	24”	28”	Hunter from Stone’s returns.
Rainfall at Cape Town	45	24”	25”	27	Hutchins from Met. Com. Reports.
Good rains Cape Town, above 29	45	2	2	6	Hutchins from Reports of Met. Com.
Light rains Cape Town below 20	45	5	3	0	Hutchins from Reports of Met. Com.
Floods or heavy rains Cape Colony (East)	66	1	1	6	Hutchins from enquiry.
Rainfall King William’s Town (South Africa)	20	25”	21”	30”	Hutchins from Records of Met. Com.
Magnetic Disturbances Europe	58	7½	8	9	Balfour Stewart.
Aurora displays Europe	60	26	42	55	Loomis.
Number of Cyclones Indian Ocean	11	7	8	13	Meldrum.
Area of Cyclones Indian Ocean	11	2	3	9	Meldrum.
Number of hurricanes West Indies	63	2	3	4	Hunter from Poëys’ lists.
Percentage of Ships lost, Lloyds	20	8·74	8·86	9·56	Jeula and Hunter.
Low Water English Rivers	63	5	2	0	Journal Royal Meteorological Soc.
Cold Winters America (Michigan)	45	4	1	0	American Meteorological Journal.
Mild Winters Europe with tendency to drought in previous Summer	66	5	1	0	Archibald Douglas.

The strongest part of the above table is the connection between sunspots and magnetic phenomena, see Loomis figures for Aurora displays, and Balfour Stewart’s for magnetic disturbances.

which no correspondence can be traced. The case is clearly a strong one in favour of the sunspot cycle. It is not five for and five against. The fact that in five places we cannot trace sunspot evidence, is no proof—is no probability, that the influence is not there. All that we can say is that in certain places the conflicting meteorological influences permit us to detect the influence of the sunspot cycle ; in other places they do not ; with the instruments now at our command. It is even possible to push the argument a step further. It is quite conceivable, that at the same place amidst conflicting meteorological influences, sunspot influence may appear for a term of years and then be again hidden from view. Vide Cyclical Diagram for Worcester (Cape Colony). Lastly, some of the facts given below, such as where an isolated drought occurs at a minimum period are of course simply suggestive.

Gustav Wex examined the recorded depth of water in the Danube, Rhine, and other European rivers between 1800 and 1867. He found that there was more water in these rivers in maximum sunspot years. If he had failed to trace the correspondence, it would have been no evidence one way or the other, till we had ascertained what was the nett result of solar energy, on the snowclad mountains where these rivers rise, as well as on the rainfall. The same remark applies to Mr. Dawson's discovery that the average water level in the great American lakes varies with the sunspot cycle.

Bret Harte in his "Notes by flood and field" gives a graphic description of the great floods in the Sacramento Valley in California. These floods occurred in 1859—60. The cyclical diagram for Cape Town shows that 1859—60 are the Storm cycle years of floods and heavy rains at the Cape. Dr. Meldrum has traced a not very clear correspondence between the sunspot cycle and the rainfall at Mauritius and some Australian stations. He did not take account of the secondary cycles. Mr. Henessey has connected the rainfall at Masouri in the Himalayas, with the sunspot cycle.

In 1876 the sunspot minimum produced the last bad famine in Madras ; in a paper dated, Adelaide, Australia, May 11th, 1878, Mr. G. Francis described the summer of 1877—8 as having been excessively dry and hot, and the water in the river Murray unusually low and warm. So far as an isolated fact has any value, it would then appear that in Australia the cyclical variation of climate is the same as in localities similarly situated in South Africa. The following extract from an Indian Forest report.—Punjaub, 1884—5, shows good rains happening punctually at the Wolfian Sunspot max. on the Himalayas:—

"The past year 1883—4 promises to be a very marked one as far as Deodar forests are concerned, for regular rain throughout May and June enabled numerous plants resulting from an abundant seeding to survive the hot weather. The oldest inhabitant fails to remember such a season for rain, and this following a prolific seed year can scarcely fail to result in an exceptional crop of young Deodars."

Dr. Karl Hesselberg in an article written a few months ago, on the climate of Sweden concludes thus: "It is, however, possible to accept a shorter periodical change in the climate than this, and theories on this point have not been wanting; but the only one that has found any support is the eleven year period corresponding to that of the sunspots."

In 1874 Dr. Schuster investigated the correspondence between sunspots and the vintages on the Rhine. His figures were criticised and the final verdict is reported to have been that in years of minimum sunspots, the Rhenish vintages are of a better quality than in maximum years. A little less rain in minimum years would I imagine produce the effect noted.

In 1873 Signor Celoria detected the eleven years cycle, in the rainfall of Milan from 1863 to 1872. More recently Dr. Gould has followed the same influence in wind and temperature observations in South America.

Dr. Wolf from an examination of the Berne rainfall registers came to this conclusion:—"*Les annés on les taches sout plus nombreuses sout aussi en general plus fertiles et plus seches que les autres; ces derniers au contraire plus humides et plus oragenses;*" or maximum years dry and fertile; minimum years wet and stormy.

To these correspondences must be added those given in my King William's Town lecture of last year. It is scarcely possible, in the time at my disposal this afternoon, to give the barest summary of the conclusions arrived at in the various investigations that have been undertaken in the endeavour to show the connection between sunspots and different meteorological phenomena. Many of these investigations have failed for obvious reasons; such as the grouping of inharmonious meteorological data, where the investigator has worked at a climate with which he had no practical or sympathetic acquaintance. Suppose, for instance, that in a climate such as that of South Africa, you mix up the Indian Ocean and the Atlantic Ocean rainfalls! The failure of such an investigation leaves the question of sunspot influence where it started!

The important principle of *retardation or lag* in sunspot influence has, as far as I am aware, not hitherto been applied.

SUNSPOTS AND ELECTRIC DISTURBANCES

The closest correspondence between well established cycles, is where the sunspot cycle is compared with the cycle of magnetic perturbations. This correspondence is now accepted as a scientific fact, by those meteorologists who do not admit that sunspots have any other influence on the weather. In such a comparison less discrimination is required than with rainfall figures. The magnetic and sunspot figures can be put together into a calculating machine, and the exact connection got out by turning a handle, so to speak. Indeed the magnetic cycle shows more regular curves than the sunspot cycle, so that the question arises whether, if the magnetic curves were readily available, students of cyclical variation of weather should not rather work with these than with the sunspot curves: the former being probably better indices of solar energy.

Says Dr. Wolf (Comptes Rendus, 1852), "*Les variations magnetiques suivent même les taches solaires, non seulement dans leurs changements reguliers, mais aussi dans toutes les petites irregulìarités.*" Again, as we have seen, Mr. Chambers, the Astronomer at Bombay, says that, at his Observatary the magnetic indications of increased solar energy *precede* the sunspots by about six months.

SUNSPOT VARIATION.

The practical object of studying cyclical variation in the past, is to get a key to unlock the door that guards the secrets of the future. In studying the past weather influences of the sunspot cycle, not only have we got to allow for *retardation* or *lag*, but for irregularities in the sunspots themselves; or, sunspot variation from the regular period of 11·11 years. What these irregularities have been, will be best perceived by running the eye over the following list of sunspots (page 69). This shows that towards the end of the last century, the black spots observed on the sun were far astray from the Wolfian cycle of 11·11 years. Exactly a century ago, in 1788, the sunspot maximum had got into the place of the sunspot minimum! Solar activity, as far as could be judged from rough observations of dark spots only, was then six years before cycle time. After this there was a long period of decline to a nearly punctual minimum in 1798. Since then, sunspots have not varied more than a year and a half from the Wolfian cycle. It was on this irregular period, at the end of the last century, that Prof. Loomis attacked the Wolfian cycle.

From 1749 to 1860, the list is by Dr. Wolf, of Zurich (monthly notices of the Royal Astronomical Society, vol. XXI., page 77.) Dr. Wolf compiled his list from various sources, and all portions of it have not the same value. Perfectly reliable sunspot observations only begin with Schwabe's work in 1825. From 1861, the figures, taken from Scott's Elementary Meteorology, have been slightly raised in relative value by multiplying by 1·03 so as to form one series with the preceding.

The sunspot variation from the 11·11 years cycle can be seen at once on the following list by remembering that (avoiding fractions of a year) double like numbers represent the minimum years in each century, thus 1811—1822 etc., are minimum years. There are nine sunspots cycles in a century so that allowing for the fraction the exact

ACTUAL OBSERVATIONS OF SUNSPOTS, show-the Variation from the 11·11 years Cycle of Wolf.

1749	63·8	
1750	68·2	MAX.
1751	40·9	
1752	33·2	
1753	23·1	
1754	13·8	
1755	6·0	Min.
1756	8·8	
1757	30·4	
1758	38·3	
1759	48·6	
1760	48·9	
1761	75·0	MAX.
1762	50·6	
1763	37·4	
1764	34·5	
1765	23·0	
1766	17·5	Min.
1767	33·6	
1768	52·2	
1769	85·7	MAX.
1770	79·4	
1771	73·2	
1772	49·2	
1773	39·8	
1774	47·6	?
1775	27·5	Min.
1776	35·2	
1777	63·0	
1778	94·8	
1779	99·2	MAX.
1780	72·6	
1781	67·7	
1782	33·2	
1783	22·5	
1784	4·4	Min.
1785	18·3	
1786	60·8	
1787	92·8	
1788	90·6	MAX.
1789	85·4	
1790	75·2	
1791	46·1	
1792	52·7	?
1793	20·7	
1794	23·9	
1795	16·5	
1796	9·4	
1797	5·6	
1798	2·8	Min.
1799	5·9	
1800	10·1	
1801	30·9	?
1802	38·3	?
1803	50·0	?
1804	70·0	? MAX.
1805	50·0	?
1806	30·0	?
1807	10·0	?
1808	2·2	
1809	0·8	
1810	0·0	Min.
1811	0·9	
1812	5·4	
1813	13·7	
1814	20·0	?
1815	35·0	?
1816	45·5	MAX.
1817	43·5	
1818	34·1	
1819	22·5	
1820	8·9	
1821	4·3	
1822	2·9	
1823	1·3	Min.
1824	6·7	
1825	17·4	
1826	29·4	
1827	39·9	
1828	52·5	
1829	53·5	
1830	59·1	MAX.
1831	38·8	
1832	22·5	
1833	7·5	Min.
1834	11·4	
1835	45·5	
1836	96·7	
1837	111·0	MAX.
1838	82·6	
1839	68·5	
1840	51·8	
1841	29·7	
1842	19·5	
1843	8·6	Min.
1844	13·0	
1845	33·0	
1846	47·0	
1847	79·4	
1848	100·4	MAX.
1849	95·6	
1850	64·5	
1851	61·9	
1852	52·2	
1853	37.7	
1854	19·2	
1855	6·9	
1856	4·2	Min.
1857	21·6	
1858	50·9	
1859	96·4	
1860	98·6	MAX
1861	79·5	
1862	60·9	
1863	45·3	
1864	48·3	
1865	31·4	
1866	16·8	
1867	7·5	Min.
1868	38·4	
1869	76·1	
1870	143·3	MAX
1871	114·5	
1872	104·8	
1873	68·3	
1874	45·9	
1875	17·6	
1876	11·6	
1877	12·7	
1878	3·5	Min.
1879	6·2	
1880	33·3	
1881	55·8	
1882	61·5	
1883	65·6	MAX
1884	65·3	
1885	53·8	
1886		
1887		
1888		
1889		Min.

minimum years in each century are 0·00—11·11—22·22—33·33—44·44—55·55—66·66—77·77—88·88—99·99. Add five years to any minimum to get the next max. Thus 1822 is a minimum year and 1827 a maximum year.

Plotting the curves of different wave lengths, Wolf says "Greater activity in the sun goes with shorter periods and, less with longer periods."

CYCLICAL VARIATION OF THE SUN'S HEAT.

This was touched upon in my King William's Town lecture. It is perhaps the most unsatisfactory part of solar physics. In a communication to the Royal Astronomical Society, dated July 16th, 1876, Professor Langley describes thus an attempt to measure the amount of heat radiated from the dark part of a sunspot, and the heat from the bright part of the photosphere :—"Sunspots do exercise a direct and real influence on terrestrial climate by *decreasing* the mean temperature of this planet at their maximum. This decrease is, however, so minute that it is doubtful whether it has been directly observed or discriminated from other changes. Its whole effect is represented by a change in the mean temperature of our globe in eleven years, not exeeeding three tenths, and not less than one-twentieth of one degree of the centigrade thermometer.

A subsequent critic points out that, the weak part of this almost negative result is that it does not take account of the absorption by our atmosphere of the obscure rays coming from the sun.

Since the whole train of solar manifestations, faculæ, prominences, red flames, and other indications of solar energy, wax and wane with the sunspots, the conclusion is almost irresistable that the sun is hotter at the maximum spot period. But it is barely possible on the surface of our earth to get instrumental proof of this cylical variation in the sun's energy. The first result on the earth of an increased heat in the sun, is increased evaporation, increased cloud, and a lower temperature. But, nevertheless, though Meteorologists are not agreed as to the exact value to be attached to solar radiation thermometers, instrumental indications, here and there, seems to show that the sun, even at the surface of the earth is hotter during the maximum period of the sunspot cycle. Speaking of India, Mr. Blandford says:—"The results of eleven stations in different parts of India showed *an incraese of at least 6 deg.* in the mean equilibrium temperature of solar radiation at the earth's surface between 1868 and 1871 (the last following a year of maximum sunspots) and this, I am inclined to think, is in defect of the truth. The variation is thus by no means inconsiderable."

In England we have the investigations of the late Mr. Joseph Baxendell. He established an 11 year cycle, for the solar radiation registers kept at the Radcliffe Observatory. We have the authority of Professors Balfour Stewart and Roscoe that there is more sunshine in London in years of maximum than in years of minimum sunspots.

The eleven-year cycle has been discovered in the winter temperature range at Kew, and in the thermometors sunk in the rock at Edinburgh.

Dr. W. Köppen's elaborate researches on sunspots and temperatures are thus described in the *19th Century* article quoted above. "He endeavoured to present the earth's temperature in connection with sunspots for the hundred years preceeding 1870. He divided the thermometer returns into two great classes; those taken within the tropics, and those belonging to the extra tropical zones. The barest summary of his researches would occupy several pages. In a carefully prepared chart, he exhibited the rainfall and sunspot curves from 1768. During the earlier part of this period, he had thermometric returns, only from the northern temperate zone. The curves do not show a coincidence. After the year 1826, when the sunspot data become more trustworthy, the case is entirely different. The curves follow each other in a most striking manner; and, indeed, he states that from 1816 to 1854 the coincidence of temperature changes with the sunspots, does not merely extend over the average length of the cycles, but reflects all the leading disturbances and peculiarities of the sunspot periods. Dr. Köppen further points out that as the period of increase from the minimum to the maximum year in the sunspot cycle is almost always shorter than the period of decrease from the maximum to the minimum, so, on the whole, is that feature reflected in the temperature changes. The parallelism in this series of returns, he says, with reference to his table dealing with the period from 1820 to 1854, is so great that there can be no question of accidental coincidence of variations independent of each other. The *19th Century* writer then adds:—" On the other hand, Dr. Köppen's figures disclose many anomalies. Thus, in the tropics, the maximum of warmth occurs a full year before the minimum of sunspots; while in the zones beyond the tropics, it falls two years after the minimum. The regularity and magnitude of the undulation of the temperature curve is most strongly marked in the tropics, and decreases towards the poles."

I quote this objection, because it has been often urged before, and I have never been able to see wherein lay the strength of the objection. The maximum temperature in the tropics falls a year before the minimum, that is to say, five years after the maximum of the sunspot cycle. It seems natural enough it should fall then. The first result of increased solar heat is, increased evaporation, increased cloud and a lower temperature. These sunspot maximum clouds decrease as the maximum declines, the sun breaks through them, so to speak, towards the end of the fourth year and produces the maximum of the heat cycle on the surface of the earth. It is only another phase of that lagging of sunspot rain with which we are familiar in Cape Colony. This lag or retardation will of course also explain the maximum temperature coming two years after minimum sunspots in extra tropical latitudes; so far as any conclusions, so broadly stated as those of Dr. Köppen, may be good.

A point on which I must acknowledge to be sceptical, but which I have not the means at present of testing, is the influence of individual sunspots on the daily weather. We have the authority of a great name—Loomis—that such a connection exists. Mr. A. G. Howard, of the Public Works Department, writes to me from Cape Town:

"As a spot approaches the centre of the sun (that is where it is directly presented to the earth) the barometer rises at Cape Town, and soon after falls."

In Cape Colony we get usually about two well-marked rises and falls of the barometer per week. The sun completes a revolution once in 25½ days, so that each spot is presented to us for about 13 days, and faces us directly for about four days. Any of the barometric maxima occuring near these four days, may be set down to any particular sunspot according to fancy. I have never seen it stated that the appearance of any remarkable spot on the sun, or of any remarkable group of spots, has been followed by corresponding barometric fluctuations. We shall see presently that our greatest barometric fluctuations in South Africa occur once every 9½ years in a secondary cycle, independent of the 11·11 year sunspot cycle. The following cutting from an Indian paper points, however, to a direct connection between sunspots and magnetic disturbances:—

"Strong earth currents were felt yesterday across the Madras Presidency, and coincidently therewith, a very considerable diminution of the earth's magnetic force. Disturbances on a gigantic scale, and with vast rapidity, were seen to take place simultaneously on the sun's disc, which has recently exhibited greatly increased activity in the formation of new spots. Four principal groups and several detached spots are now being carried by the sun's rotation across his disc. The principal group, which will be near the sun's central meridian on Wednesday and Thursday, consists of more than thirty distinct spots of various sizes. The penumbra which encloses the whole group measures nearly 140 seconds of arc, or about a fourteenth part of the sun's diameter, which expressed in miles may be more readily understood as an irregular but nearly circular enclosure of sixty-one thousand miles across, more than seven and a half times the diameter of our little world. The revival of solar and magnetic activity gives reasonable hopes of favourable seasons in this Presidency, for this and a few following years, a corresponding reverse being probably the fate of Northern India." The author, Miss Pogson, writes from the Madras Observatory.

CYCLICAL VARIATION OF TEMPERATURES AT THE CAPE.

Coming to the Southern Hemisphere with its immense evaporating surface, we find, as would be expected, the inversed relation prevailing. In the "Results of Astronomical Observations" at the Royal Observatory, Cape Town, published by Mr. Stone in 1856, the curves of sunspot frequency and the inversed curves of yearly mean temperatures are placed side by side. They exhibit an unmistakable relation.

Appendix G. of the yearly meteorological report for 1883 gives "The mean temperature of the air for each month of the year for the years 1871 to 1882, deduced from the Abstract Books at the Royal Observatory, Cape of Good Hope." We have here the mean temperature for eleven years, running nearly from sunspot maximum to sunspot maximum. I have continued the series but do not feel sure that I have applied the same corrections, so that the results may not be directly comparable. In the table this want of continuity is shown by a line separating the figures into two series. So far as conclusions are valid drawn from little more than one cycle, these figures give the following result. (Page 75).

A high mean yearly temperature precedes by nine or ten months the max. of sunspots.

A higher mean yearly temperature precedes by nine or ten months, a very important period in the rainfall of S. Africa, the lag-rain of the sunspot max.

The highest mean yearly temperature precedes by nine or ten months the min. of sunspots.

The year of the Storm cycle 1878, was nearly the year of lowest temperature. The quite lowest temperature was the following year 1879. In fact, allowing for the half year of the 9·5 year cycle, we may say that the lowest temperature coincided with, or slightly followed, the Storm cycle year Summarizing, we may write this connection thus :—

Temperatures	Cycle
High	Max of Sunspots.
Higher	Lag-rain of Sunpots max.
Highest	Min. of Sunspots.
Lowest	Storm cycle year.

Further data may modify these conclusions. Dr. Köppen, it will be remembered,found for extra tropical latitudes, that max. temperatures followed two years after minimum sunspots. This would be generally true for S. Africa, the exception being mitigation rains falling then.

ROYAL OBSERVATORY: CAPE TOWN.

Year.	Mean Temperture.	Cycle.	Connection	Remarks.
1871	61·31		High temp.	Appendix G. Meteorological Report for 1883.
1872	61·13	Max. Sunspots.		
1873	61·79		Highest but one.	
1874	60·62	Lag rain of Sunspot max.		
1875	61·09			
1876	61·32			
1877	62·07		Highest temp	
1878	60·93	Min. Sunspots & Storm cycle.		
1879	60·47		Lowest do.	
1880	61·48			
1881	60·86			
1882	61·61			

NEW SERIES.

1883	[60·04]	Max. Sunspots.		From 6 am reading, doubtful	Stone's Factors.
1884	60·65			From 8 am reading, good.	
1885	60·75	Lag rain of Sunspot max.	High.	Do. do.	
1886	61·41			Do. do.	
1887	60·35			Do. do.	
1888		Storm Cycle.			

(The expressions used in the column "cycle" will be explained later. They are introduced here so as to avoid having to recur to this portion of the subject).

Influence of the Sunspot Cycle on the Rainfall of South Africa.

As we have seen was the case in India the evidence on this head separates into three branches of enquiry.

1st. Meteorological records.

2nd. The collection and grouping of Statistics relating to remarkable seasons.

3rd. Prices of food grains.

METEOROLOGICAL RECORDS.

Of Meteorological records the best long-period figures we have are those from the Cape Town Observatory. In the general table at page 64 you see these figures grouped by Sir W. W. Hunter and by myself. In the accompanying diagram I have plotted those figures, and the curve shows exactly the influence of the Sunspot cycle on the rainfall, at Cape Town between 1841 and 1870. I have here a table* in which the Cape rainfall figures are brought up to date, and grouped in two ways :—

(*a.*) into max., min., and intermediate years, according to situation on the sunspot cycle.

(*b.*) into max. and min. years only.

The result of the first is shown on the general table. The result of the second grouping is that the mean rainfall at Cape Town is 23·43 inches in minimum sunspots years, and 27·15 inches in maximum sunspots years. My more recent figures show a weaker correspondence with the sunspot cycle than was obtained by Messrs. Norman Lockyer and Hunter, for the reason that 1877 and 1878, though years of minumin sunspots, were years of exceptionally heavy rainfall (35" and 41"). There was evidently a disturbing influence at work here, strong locally in its action, but barely traceable in rainfall stations away from the limited Atlantic rainfall.

THE STORM CYCLE.

This disturbing influence caused me much thought, the more so that it seemed to be increasing in power; and threatened to obliterate that correspondence between sunspots and rainfall which in Herschel's time, and even up to 1876, stood out so clearly! The disturbing influence is first traceable in the heavy rainfall of 1859-60 and again in 1869-70. Early maxima of observed spots will explain these to some extent. Lag and a late maximum of observed spots, will also explain, though not very satisfactorily, the heavy rainfall of 1888. But the unprecedentedly heavy rainfalls of 1877 and 1878, could not be coaxed into the sunspot cycle! They remained unexplainable till my friend, Mr. Fry, the Sec. to the Meteorological Commission, allowed me to take a copy of the plotted curves of rainfall at the Royal Observatory. These curves show clearly enough that whatever the nature of the disturbing influence in the Cape Town maximum rainfall figures, the influence occurs at regular intervals of nine or ten years. The disturbing influence only effects certain very heavy rainfalls, leaving the droughts and the moderately heavy rainfalls following closely the ups and downs of the sunspots curves.

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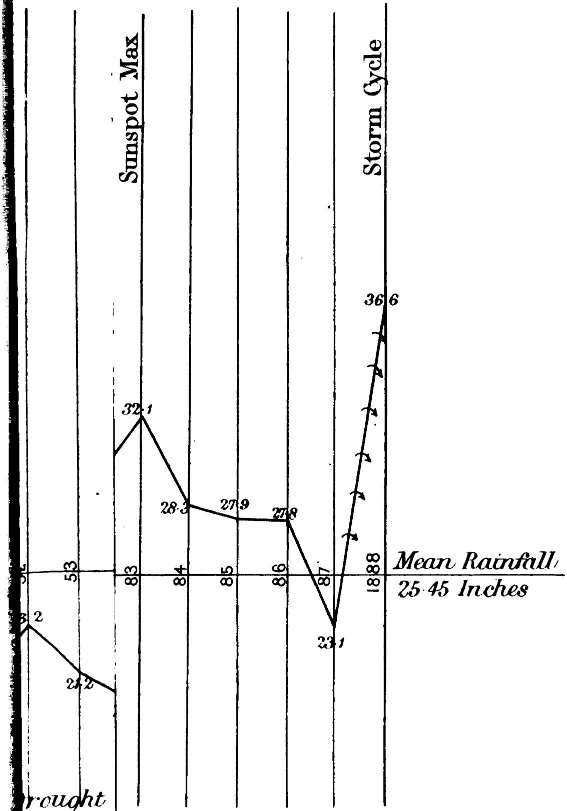
*Not reproduced as this table is now superseded by the discovery of the secondary cycles.

With the maximum rainfalls at Cape Town are associated violent storms over the rest of South Africa, and notably shipwrecks at Port Elizabeth. This we shall notice presently under the head of remarkable seasons. Without speculating on the cause of the disturbing influence, it will be best to take the facts as we find them, and to recognize in the Meteorology of South Africa, a secondary cycle with a period of 9 or 10 years. This secondary cycle being associated with low readings of the barometer, floods, and storms, I shall, for clearness, refer to it as the "Storm Cycle."

The Storm cycle brings floods to Ceres, to Clanwilliam, and to the Atlantic rainfall stations generally. Further inland, it is the only cyclical influence that has any practical interest for the people of Worcester—*Vide* discussion of meteorological records page 87. In fact it bears the same relation to the few inland Atlantic rainfall stations that does the lag-rain of the sunspots max. to the numerous inland Eastern Stations. The Storm cycle brings the lowest mean yearly temperatures to Western Stations. The Storm cycle appears sufficiently clearly on the Mauritius records of

YCLIC


Sunspot Max
Storm Cycle
36·6
32·1
28·3
27·9
27·8
23·1
2
2 2
52
53
83
84
85
86
87
1888
Mean Rainfall
25·45 Inches
rought

rainfall. At Mauritius the Storm cycle rain does not always appear on the same calendar year as at Cape Town, one locality having winter and the other summer rains. In 1859 the Storm cycle rains fell within the same calendar year at both places. Its early appearance by a year (plus or minus a fraction of a year) in 1868 seems to account for the heavy rainfall that then extended over Eastern South Africa, as far as Uitenhage. In the fragment of Australian rainfall records in my possession, the Storm cycle appears once only at Brisbane.

CYCLICAL DIAGRAM OF RAINFALL AT CAPE TOWN.

The figures on the accompanying diagram are taken from the records of the Royal Observatory Cape Town. They extend from 1841 to 1888. The only interpolation in this long series is that of the three unimportant months January, February, and March, in the first year 1841. The particular monthly average for each of these three months has been interpolated. The diagram sufficiently explains itself: the rainfall curves are plotted in the usual manner, and the names of the cycles are printed opposite the points of the rainfall curve to which they correspond. This method seemed clearer than superimposing the sunspot curves, more especially, as the remarkable correspondence of the Cape Town rainfall is *not with the observed sunspots*, but with the Wolfian Cycle of 11.11 years.

To first consider droughts ; you will observe that periods of drought correspond exactly with minimum sunspots, allowing for the two years of interruption caused by the Storm Cycle falling in 1877-78.

CYCLES OF DROUGHT AT CAPE TOWN.

1841 1849	Drought of the sunspot minimum in 1844. Drought most intense in 1844. Cyclical mitigation in 1842.
1851 1858	Drought of the sunspot minimum in 1855, with a slight irregular mitigation in 1852, and the cyclical mitigation in 1855.
1863 1868	Drought of the sunspot minimum in 1867, with cyclical mitigation in 1867, and the end of the drought broken by the Storm cycle in 1869

1873 1881 Drought or average rain 1873 to 1875, then three years Storm cycle rain, then two years severe drought, the cyclical mitigation in 1880 being anticipated by the more powerful Storm cycle.

CYCLES OF FLOODS AND HEAVY RAINS AT CAPE TOWN.

Here, looking at the cyclical diagram, it will be seen I trace two distinct cycles running together in 1850 and thence gradually separating :—

(1.) The Sunspot cycle of 11·11 years.
(2.) A secondary cycle (the Storm cycle) of 9.5 years.

YEARS OF MAX. RAINFALL AT CAPE TOWN.

(*Vide* Cyclical Diagram).

YEAR.	SUNSPOT MAX.	STORM CYCLE.	REMARKS.
1850	33·5	33·5	Both Cycles coinciding.
1859		36·7	
1862	32·6		
1869		32·3	
1872	29·3		
1878		41·0	
1883	32·1		
1888		36·6	
Sum	127·5	180·1	
Mean	31·87	36·02	

Thus the Mean Rainfall for a Sunspot Max. year is 31·87
and „ „ „ Storm Cycle „ 36·02

In sunspot maximum years the variation from the average is remarkably small. The greatest variation has been only 2·57 in.—below in 1872. In Storm cycle years the greatest divergence from the average has been 4·98 in. —above in 1878.

A feature of this sunspot rainfall is its small retardation from the 11·11 year cycle of Wolf (see page 69). The mean retardation is only 0·58 years. The greatest retardation is only 1·38 years in 1862. The least retardation is 0·17 years in 1883.

RETARDATION.

	YEARS.
In 1850	0·50
„ 1862	1·38
„ 1872	0·28
„ 1883	0·17
Sum ...	2·33
Mean ...	0·58 say 7 months.

For the Storm cycle we have four periods : two of 9, and two of 10 years. The mean term of this secondary cycle is thus 9·5 years.

Mr. A. G. Howard of the Public Works Department, Cape Town, who has studied the cyclical variations of the weather on his side of the colony, believes in a connection between the weather and the conjunctions and oppositions of Jupiter and Saturn. I have not Mr. Howard's practical acquaintance with the weather at Cape Town ; looking, however, at the meteorological records it does not appear that this period of 9·93 years will even partially explain the facts. Loomis, it will be remembered, offered this period as a correction to Dr. Rudolf Wolf's cycle of 11·11 years. But, with the sunspot cycle of 11·11 years, and the secondary cycle of 9·5 years, we obtain a complete key to the Cape Town weather. It only remains now to use this key to unlock the secrets of the future!

In the light of what we have been considering it is easy to construct a forecast of the weather for the next 50 years. It is not conceivable that the cycles, which have rolled through the last half century so regularly, will not continue to do so for the next 50 years. Turning once more to the cyclical diagram for the Cape Town Observatory, you see that since 1841, during three Sunspot cycles and four Storm cycles, the weather has proceeded on the following lines :—

Sunspot Rainfall.—A mean retardation of 7 months.

Storm Cycle Rainfall.—If we take the Storm cycle as 9·5 years, since the actual rain came at intervals, of 9, of 10, of 9 and of 10 years respectively ; it came as punctually as possible; bearing in mind the fact, that Cape Town rain is necessarily winter rainfall.

Sunspot Droughts.—The average duration of drought has been six years. It lies equally on both sides of the year of minimum sunspots when not modified by the interference of the rainfall of the secondary cycles. There is a slight mitigation of one or two years towards the middle of each drought. These mitigation rains scarcely noticeable in Atlantic rainfalls are of great importance in Indian Ocean rainfalls under which they will be discussed. In the past, these mitigation rains have come at intervals of 13, of 12, and of 13 years, thus indicating a secondary cycle with a mean period of 12·7 or more probably 12½ years.

In the following forecast drought means any year in which the rainfall is below the average:—(Pages 83 and 84).

In this forecast the only uncertain feature is the position of the mitigation rain. This is one year of average rainfall occuring towards the middle of the drought of the sunspot minimum. These rains, when the 12·5 year mitigation cycle falls within the drought years of the sunspot minimum, can be located with a fair chance of certainty. Otherwise we have to surmise either unbroken droughts or irregular mitigation rains. See below page 109 in forecast for Indian Ocean rainfalls where the mitigation rains are far more important than in Atlantic rainfalls.

An inspection of this table shows that between 1897 and 1925 the regular droughts of the sunspot minimum may be severe in character.

POSSIBLE ERRORS.

A possible source of error in this forecast may be the variation of observed sunspots from Wolf's cycle of 11·11 years—see page, 69. But, running the eye over the cyclical diagram for the Royal Observatory, Cape Town, it will be seen that the two weather cycles have pursued their course uninfluenced by spot variation from the Wolfian cycle; or, in other words, the rainfall at Cape Town, like some magnetic phenomena, follows the 11·11 year cycle more regularly than the sunspots, as far as we

ATLANTIC RAINFALL,—CAPE TOWN AND WEST ONLY.

FORECAST OF SEASONS

for the period 1888 to 1938.

YEAR	SUNSPOT CYCLE. 11·11 yrs	STORM CYCLE. 9·5 yrs	MITIGATION CYCLE. 12·5 yrs	FORECAST.
1889	Min.	yr. after max.		Rainfall intermediate.
1890				Drought.
1891				Drought.
1892			Max.	Cyclical mitigation : one year of average rain.
1893				Rainfall intermediate. [Town Observatory.
1894	Max.			Good rain within an inch or two of 32in. at Cape
1895				Good or average rain.
1896	Lag			Drought or average rain on the coast, probably more rain at some inland western stations like Ceres.
1897		Max.		Heavy rains west (about 36in. at Obs.) extending coastwise ; high winds east ; storms general.
1898				Rainfall intermediate.
1899				Drought } Irregular mitigation (average) rain about here?
1900	Min.			Drought
1901				Drought
1902				Drought
1903				Drought
1904				Rainfall intermediate or average. [Observatory
1905	Max.		Max.	Good rain within an in. or two of 32in. at Capetown
1906				Rain good or moderate.
1907	Lag	Max.		Heavy rains west (about 36in. at Obs.) extending coastwise ; high winds east ; storms general, and most probably general heavy rain.
1908				Rainfall intermediate.
1909				Drought } Irregular mitigation (average) rain about here?
1910				Drought
1911	Min.			Drought
1912				Drought
1913				Drought
1914				Rainfall intermediate.
1915				Rainfall good or moderate.
1916	Max.	Max.		Heavy or good rain west extending coastwise ; high winds east ; storms general ; a season similar to 1850.
1917			Max.	Rainfall good or moderate.
1918	Lag			Drought or average rain on the coast, probably more rain at some inland western stations like Ceres.
1919				Drought.
1920				Drought.
1921				Drought. } Irregular mitigation (average) rain about here?

FORECAST.—*Continued.*

YEAR	SUNSPOT CYCLE. 11·11 yrs	STORM CYCLE. 9·5 yrs	MITIGATION CYCLE. 12·5 yrs	FORECAST.
1922	Min.			Drought.
1923				Drought.
1924				Drought or moderate rain.
1925				Rainfall intermediate.
1926		Max.		Heavy rain west (about 36in. at Obs.) extending coastwise; high winds east; storms general.
1927	Max.			Good rain this or next year.
1928				Rainfall good or average.
1929	Lag			Drought or average rain on the coast, probably more rain at some inland western stations like Ceres. [or later.
1930			Max.	Drought or mitigation (average) rain this year
1931				Drought.
1932				Drought.
1933	Min.			Drought.
1934				Rainfall intermediate.
1935		Max.		Heavy rain west (about 36in. at Obs.) extending coastwise; high winds east; storms general.
1936				Good rain.
1937				Rainfall average or drought. [Observatory.
1938	Max.			Good rain within an inch or two of 32in. at

are able to observe them. For instance, a remarkable feature in the observed sunspots of recent years was the powerful maximum of 1870 when the relative number of spots rose to 143·3. "The year 1870 was characterized by an exuberance of solar energy which is without parallel since the beginning of systematic observations." The groups are described as abundant and striking. "A large number of groups completed 3, 4, or even more, revolutions, before finally collapsing."—Monthly Not. Royal Astronomical Society; Vol. 31, page 79. Looking again at the cyclical diagram for Cape Town it will be seen that this most powerful maximum of sunspots produced the weakest rainfall maximum there shown; and what is more, though the sunspot maximum was two years before its time the rainfall maximum came punctually to the Wolfian cycle in 1872. Again in 1859-60 the sunspot maximum came nearly one year too soon but the rainfall maximum was 1·38 years late in 1862. Almost exactly the same thing happened in 1850, the divergence being rather greater. In 1883 both sunspot maximum and rainfall maximum were punctual to the Wolfian cycle. I therefore attach no importance to sunspot variation from the Wolfian cycle as a source of error in this forecast.

Another small source of error lies in the period of the Storm cycle. The value here assigned to it, 9·5 years, is founded on four cycles, and is probably correct within a few months; but should the experience of future years show any material alteration in this value, it will be easy to apply the correction to the forecast. It will be seen presently, in discussing floods at Ceres and remarkable seasons generally, that the Storm cycle reckons back correctly for seven cycles with the period of 9·5 years—from 1888 the present Storm cycle year to 1822·5—so that this figure must be considered as coming very close to the actual value of the cycle. One old date in Cape History, page 122 fixes a precise value to the Storm cycle of 9·43 years.. This is so near the well-established value of 9.5 years that the difference need not be considered. In a forecast for 50 years, it would only amount to four months at the end.

Of course it will not be forgotten that this forecast applies to Atlantic rainfalls only. At eastern stations the cyclical phenomena are materially different, and their forecast will show little or no connection with that here given for western stations. A separate forecast for eastern stations will be found later when discussing Indian Ocean rainfalls.

Before quitting the sunspot and secondary weather cycles at Cape Town, the following on a sunspot and secondary barometric cycle in India may be noted:—"At stations in tropical India, the height of the barometer is subject to an inequality of a ten-yearly period as was pointed out by Mr. F Chambers in *Nature*, Vol. 18, page 567. Mr. Blandford has also shown (*Nature*, Vol. 21, page 477) that a similar inequality is observable in other parts of the world. The ten-yearly inequality of pressure observed in Southern India appears, however, to be considerably modified north of the tropics, and perhaps *converted into one having two maxima and two minima in a* *period of ten or eleven years.*"—Indian Meteorological Memoirs, Vol. I., page 329.

From the character of the past Storm cycle year 1888, and an inspection of the wreck record given at page 121, it seems that both the secondary cycles observable in the rainfall of South Africa are characterized by strong barometric disturbances. The following may be taken as indicative of the origin of the rain in the four South African rain periods:—

1. Sunspot max....	Increased evaporation.
2. Lag rain of sunspot max.	Delayed precipitation.
3. Mitigation cycle	Cyclonic.
4. Storm cycle	Cyclonic with very strong barometric disturbances.

Numbers 2 and 3 are eastern rain periods. We shall now proceed to discuss the rainfall at various stations in South Africa taking them in order from west to east—when eastern rainfalls will be considered and a forecast given for eastern seasons.

INLAND STATIONS: ATLANTIC RAINFALL.

Ceres.—Ceres is a village situated 55 miles inland from the Atlantic, and at an elevation of 1,500 feet above sea level. It has a remarkably healthy climate, cold and bracing, as much from its Atlantic breezes as from its moderate elevation. It is picturesquely surrounded by mountains whose barrenness, under a plentiful rainfall, is explicable only by the fact that the rain comes almost entirely in winter when the temperature is too low for the indigenous Cape flora. The mean rainfall at Ceres is 38 inches. The monthly curves of this rainfall (*vide* Gamble's appendix to the Report of the Meteorological Commission for 1884) are practically identical with the monthly curves of the Atlantic rainfall at Cape Town. I visited Ceres shortly after the floods of this year and was informed that the floods occur regularly every 9 or 10 years. The previous floods were in 1878 and thence backwards about every ten years. There is a remembrance of a terrible flood in 1822. Reckoning back the Storm cycle in periods of 9·5 years from 1850—*vide* cyclical diagram—we get to 1822·5, i.e., the winter of 1822 the exact date of the flood. Thus the meteorological records for two cycles, and the recollections of the inhabitants extending back to 1822, agree in making the years of flood at Ceres coincide with the Storm cycle.

The meteorological records for Ceres only extend back to September 24th, 1877. From that date the following are the yearly rainfalls:—

CERES YEARLY RAINFALL.

YEAR.	RAINFALL.	CYCLE.
1878 floods.	52·91	Storm Cycle.
1879	29·62	Drought of sunspot minimum.
1880	29·97	
1881	32·76	
1882	31·98	
1883	44·00	Sunspot max.
1884	28·18	
1885	41·04	Lag rain of Sunspot max.
1886	38·40	
1887	35·23	
1888 floods.	62·43	Storm Cycle.
Sum	426·52	
Mean of 11 yrs.	38·77	

An inspection of the rainfall record bears out the assertion of the inhabitants with regard to floods. It shows, moreover, that the Atlantic inland rainfall corresponded with the Atlantic coast rainfall with one exception, i.e., the lag rainfall for 1885. Twelve inches fell in June of that year. Four months afterwards the heavy rains set in that broke up the drought in the east of the Colony. Time will show whether this is a mere coincidence or whether there is here a clue towards an explanation of that retardation or lag which we shall see is so universal in eastern rainfalls.

Worcester.—The elevation of Worcester is only 780 feet. With its mean rainfall of only 12·84 inches it illustrates the rapid weakening inland of the Atlantic rainfall. A study of the rainfall table annexed shows this curious result. For the first ten years, 1862 to 1871, there is a remarkably regular correspondence with both the Sunspot and Storm cycles. There is then a gap of 4 years in the records. From 1876 when they begin again up to date, there is an irregular correspondence with the Sunspot cycle, while the Storm cycle acts with undiminished force. As matters now stand, the Storm cycle is practically the only cycle that the inhabitants of Worcester need concern themselves with. The lag rains have no appreciable influence on the Worcester rainfall.

YEAR.	RAIN-FALL.	CYCLE.	INTERPOLATIONS.
1862	21·24	Year after max. of sunspots.	
1863	14·55	Lag rain of sunspot max.	
1864	8·79	Drought of sunspot min. very regular.	
1865	5·33		
1866	8·82		
1867	11·30		
1868	11·31		
1869	20.33	Storm cycle.	
1870	16·75		
1871	11·48		
1872	no record	Max. of sunspots.	
1873			
1874		Lag rain of sunspot max.	
1875			
1876	16·88		[interpolated from average.
1877	18·44		April, May, June, December,
1878	24·32	Storm cycle brought floods.	Jan. interpolated from average
1879	10·97	Drought of sunspot min.	This year's rainfall at Ceres—
1880	9·74		29·62, divided by 2·7.
1881	8·65		
1882	10·43		
1883	10·39	Max. of sunspots.	
1884	7·61		
1885	11·92	Lag rain of sunspot max.	
1886	11·40		
1887	10·18		
1888	14·54	Storm cycle brought floods.	
Sum	295·37		
Mean of 23 yrs.	12·84		

KAROO RAINFALL.

For Karoo rainfalls we have the valuable Graaff-Reinet records, and numerous others for shorter or broken periods.

Goliad's Kraal for instance (Graaff-Reinet district) has records going back for exactly a quarter of a century; and it is complete with the exception of one year—1872. The Karoo rainfall seems simply the dry extension westward of the eastern rainfall. It appeared to be a sufficiently homogenous climatic area to combine, for purposes of study, the rainfall returns from the various stations. I have, therefore, brought these together into one series. Wishing to keep the good Graaff-Reinet records intact, I have studied them by themselves as a separate series, and have thrown into another short series, the rainfall returns from Goliad's Kraal, Rietfontein, Camfer's Kraal, and

YEAR.	GOLIAD'S KRAAL.	RIETFONTEIN	CAMFER'S KRAAL.	AMALIENSTEIN.	MEAN.
1863	16·98				
1864	13·83				
1865	6·18				
1866	13·85				
1867	17·06		9·34		
1868	13·95	6·92	*9·10	21·19	12·79
1869	11·01	12·91	6·18	13·24	10·83
1870	21·06	16·95	7·80	15·74	15·38
1871	8·73	11·06	9·40	11·91	10·27
1872	*17·48	16·47	11·15	14·15	14·81
1873	8·57	7·35	6·88	10·73	8·38
1874	19·75	11·58	10·16	10·74	13·08
1875	14·63	20·45	13·10	17·48	16·41
1876	21·53	22·03	13·81	20·60	19·49
1877	9·33	8·04	3·84	9·76	7·74
1878	11·11	10·93	6·51	13·10	10·41
1879	16·07	9·92	8·94	13·17	12·02
1880	13·43	6·62	7·19	12·31	9·88
1881	20·51	5·09	8·01	8·64	10·56
1882	12·68	12·29	8·93	10·86	11·19
1883	9·58	8·63	3·10	15·93	9·31
1884	11·09	*10·49	7·94	13·82	10·83
1885	11·34	9·64	9·19	12·88	10·76
1886	18·83	10·23	7·42	12·39	12·21
1887	14·76	17·31	8·34	13·78	13·54
1888	13·39	12·75	5·34	15·42	11·72
Sum	349·25	237·17	172·57	287·84	251·61
Mean of 21 yrs.	16·63	11·29	8·21	13·70	11·98

* Reduced from the mean of the other Stations.

Amaleinstein. In the combined series the only cyclical variation that can be traced is that of a late lag rain of sunspot max.—the retardation being about 3 years.

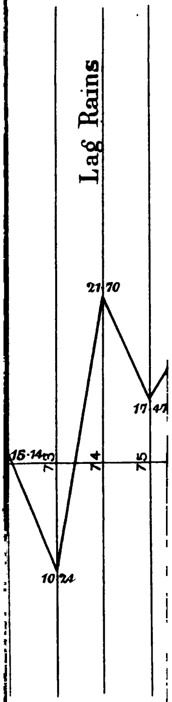
The foregoing table (page 89) is the combined rainfall for the 4 Karoo Stations.

Graaff-Reinet.—Graaff-Reinet, one of the oldest towns in the Colony, has the best meteorological records after Cape Town. Counting 1888, it has rainfall figures for 28 years without a break. Graaff-Reinet has an elevation of 2,500 feet and is distant 123 miles from the sea. It is fairly centrally situated as a representative Karoo station, but

KAROO RAINFALL.—GRAAFF-REINET.

YEAR.	RAIN.	CYCLE.	INTERPOLATIONS.
1861	12·41	(Sunspot max.)	
1862	6·96		
1863	18·35	Lag rain cf Sunspot max.	
1864	13·55		
1865	8·20		The record is without break of any sort.
1866	14·24		
1867	18·20	Cyclical mitigation.	
1868	16·46		
1869	13·84		
1870	18·42	Irregular mitigation.	
1871	16·47		
1872	15·14	Sunspot max.	
1873	10·24		
1874	21·70	Lag rain of Sunspot max.	
1875	17·47		
1876	21·01		
1877	10·91		
1878	9·98		
1879	13·72		
1880	16·20	Cyclical mitigation.	
1881	15·09		
1882	14·08		
1883	11·38	(Sunspot max.)	
1884	11·53		
1885	14·54		
1886	24·30	Lag rain of Sunspot max.	
1887	16·92		
1888	14·63		
Sum	415·94		
Mean of 28 years.	14·85		

AF REINI



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being towards the south-eastern side of the Karoo plateau it gets more rain than stations on the north-western side. Like other Karoo stations, its rain is brought by thunderstorms precipitating the summer clouds brought up by the south-east trade winds. The rainiest month is from the middle of February to the middle of March, the south-east trade wind being at its maximum in February. The cyclical period that is of the greatest practical interest to the people of this part of the Karoo is that bringing the lag-rain of the sunspot maximum. At Graaff-Reinet we have this period for three sunspot cycles. It has never

APPROXIMATE FORECAST FOR EASTERN KAROO SEASONS.

YEAR	SUNSPOT CYCLE.	MITIGATION. CYCLE.	FORECAST.
1889	Min.		Years of drought with one or two years of mitigation rains averaging 17 inches at Graaff-Reinet towards the middle of the drought, most probably in 1892 (the year of the 12½ year cycle).
1890			
1891			
1892		Max.	
1893			
1894	Max.		Bad drought this or following year.
1895			Drought will break this or the following year.
1896	Lag		The good lag rain of the sunspot max. is now due.
1897			A good or fair season.
1898			A fair season or drought.
1899	Min.		Years of drought with one or two years of mitigation rains averaging 17 inches at Graaff-Reinet towards the middle of the drought. The mitigation rains may partially fail this cycle, rendering the drought unusually severe.
1900			
1901			
1902			
1903			
1904			Drought or moderate rain.
1905	Max.	Max.	Good rain.
1906			Drought or moderate rain.
1907	Lag		The good lag rain of the sunspot max. is now due.

failed to bring abundant rain. So much can be gathered by running the eye down the rainfall figures. The general connection with the sunspot cycle is shown on the cyclical diagram for Graaff-Reinet. The two "cyclical mitigations," the one irregular mitigation, the prolonged lag-rains from 1874 to 1876, are notable features.

Sunspot maximum rain it will be noticed, has no appreciable influence on the Karoo rainfall. The effect of the powerful "mitigations" in the Karoo rainfall has been to throw the drought into two periods :—

(*a*). The worst before the cyclical mitigation.
(*b*). Less severe, before the abundant lag-rains.

The cyclical variation of the eastern Karoo climate differs in no material respect from the eastern climate generally; of which, in fact, it is but the dry extension westward over the continent.

EASTERN METEOROLOGICAL RECORDS.

Coming to the east of the Colony, we have records going back for more than 20 years, in the cases of Uitenhage, Port Elizabeth, Grahamstown, King William's Town, and Aliwal North.

Uitenhage is situated close to the South Eastern Coast, on the verge of the Eastern Rainfall, Grahamstown has a more eastern climate, King William's Town a more purely eastern climate—and it may be added, flora. Aliwal with its perfectly dry winter resembles the eastern climate of Natal (inside the coast line), the Orange Free State, and the Transvaal.

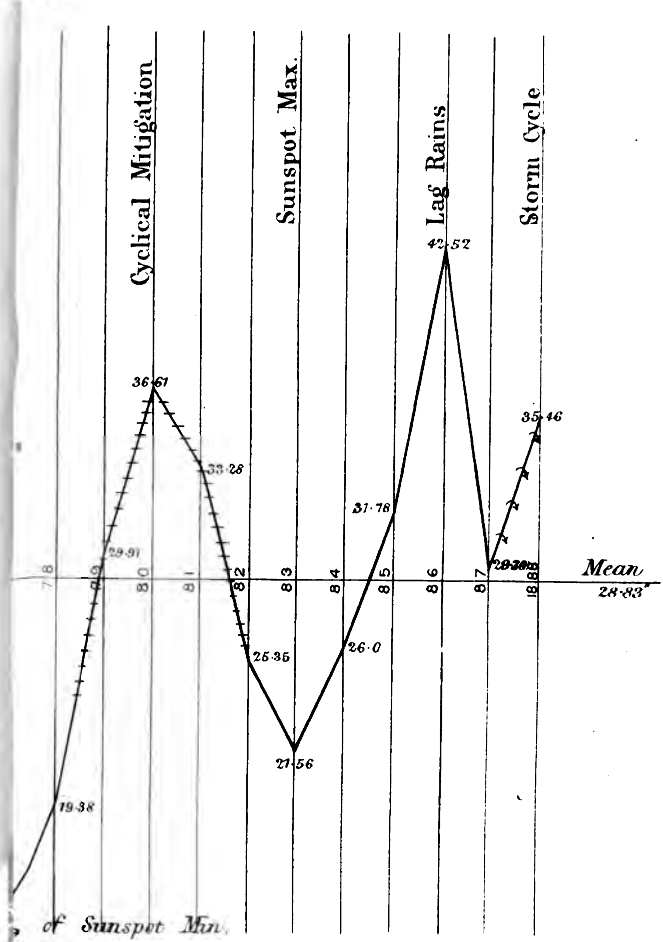
Uitenhage.—Elevation 200 feet, distance from coast 16 miles. Geopraphically, Uitenhage marks the beginning of the eastern climate. Its forest vegetation is purely eastern, though naturally of a stunted character with a rainfall scarcely more abundant than that of the Karoo. Mr. Gamble's diagrams of monthly averages, show that the rainfall of Uitenhage, excepting a little drought in June, is pretty evenly distributed throughout the year. The same feature is noticeable in the eastern coast climate of East London, and the southern coast climate of Mossel Bay. The cyclical features of the Uitenhage climate are a general resemblance to the Karoo climate, with the exaggerated "mitigation" rains of eastern stations—compare the Uitenhage cyclical diagram with the cyclical diagram for Graaff-Reinet and those for eastern stations. In fact at Uitenhage, as in other eastern stations, the "mitigation" rain is stronger than that brought by the regular sunspot periods. This would tend to make the droughts short lived were it not that the lag-rain of the sunspot maximum usually so strong and punctual in eastern rainfalls, is at Uitenhage late and comparatively weak. This was the cause of the last severe drought extending from 1881 to 1885 (both years inclusive). At Uitenhage we see comparative weak and rather late lag rains ; still weaker or uncertain are the rains of the sunspot maximum and the Storm cycle; the cyclical mitigation rains are punctual, and in 1880 gave the heaviest rainfall on record, viz., 22·37 inches.

UITENHAGE RAINFALL.

YEAR.	RAIN. INCHES.	CYCLE.	INTERPOLATIONS.
1860	19·21	Sunspot Max.	
1861	12·51		
1862	12·40		
1863	19·22	Lag rain of sunspot max.	
1864	15·00		
1865	8·47		
1866	11·88		
1867	18·02	Cyclical mitigation.	
1868	15·89		
1869	16·40	Storm cycle.	
1870	18·34		
1871	11·02		
1872	16·30	Sunspot Max.	
1873	(9·09)		Somerset East x0·74--approximate
1874	(15·57)		Do. do. do.
1875	18·26	Lag rain of sunspot max.	
1876	17·48		
1877	(8·38)		Somerset East x0·74--approximate
1878	18·15	Storm cycle.	
1879	17·91		
1880	22·37	Cyclical mitigation.	
1881	13·63		
1882	14·49	Sunspots Max.	
1883	12·74		
1884	10·38		
1885	13·01		
1886	16·25	Lag rain of sunspot max.	
1887	13·50		
1888	20·98	Storm cycle.	
Sum	436·85		
Mean of 29 years.	15·06		

Port Elizabeth.—The first report of the Meteorological Commission gives observations from July, 1875. Appendix D. to the report for 1885. "Rainfall statistics not hitherto published" gives previous observations at Port Elizabeth back to the year 1867. But I find it difficult to reconcile the observations at Port Elizabeth taken before and after 1875. The mean of the first is 25·99, the mean

VN. CAPE COLONY: EAST.



of the second is 20·46. Are we to assume a secular change in the climate of Port Elizabeth, amounting to about 25 per cent. from the year 1875? We might imagine Port Elizabeth to be blessed with an abnormal wet period from 1867 to 1876, but there is nothing in the vegetation of the country to indicate the existence of such a wet period. I have heard of no tradition of such a wet period. Worst of all, an examination of the Uitenhage rainfall register shews no such wet period there. Uitenhage is distant only 18 miles from Port Elizabeth and 15 miles from the coast. It has the same elevation as the Port Elizabeth Observatory, 200 feet, and a rainfall similar to Port Elizabeth but less in amount. It seems natural therefore to suppose that previous to the organization of the Meteorological Commission in 1875, the rainfall records from Port Elizabeth are untrustworthy. So far as the records from Port Elizabeth may be considered trustworthy, they show that the cyclical variation of its climate is the same as that of Uitenhage, with the exception that the sunspot maximum period brings a more regular rainfall. This seems to be a feature of all places on the coast line.

GRAHAMSTOWN METEOROLOGICAL RECORDS.

Grahamstown—the Athens of the East—has more gaps in its meteorological records than any rainfall examined. But as the Grahamstown records go further back than any others of the purely eastern rainfalls for Cape Colony, an endeavour has been made to patch up the records by interpolating for those months that are wanting:

(*a.*) The average (of 22 years) for the same month in other years.

(*b.*) The actual rainfall at a neighbouring station applying a correction deduced from the average monthly rainfall at each of the two stations.

Thus if G represents the average rainfall for any particular month at Grahamstown and K for the same month, say at King William's Town:

$$\frac{G}{K} = R$$

Then interpolated rainfall at Grahamstown = actual rainfall at King William's Town × R.

The (*a*) method has been used only for one month of the first year when there were no records from neighbouring stations to fall back on.

Studying these figures and those of other eastern stations, with the aid of the cyclical diagrams, we see; first, the marked contrast between the eastern and western rainfalls. The beautifully regular cycles of the Atlantic rainfall have disappeared, and in their place we have the following cyclical indications:—

(1) The rainfall of the sunspot max is uncertain near the coast, and scarcely noticeable inland.

(2) Good strong rains—the "lag" rains—always occur two years (rarely three years) after the sunspot maximum.

(3) Droughts occur during the intervals of cyclical rains usually about the sunspot minimum.

(4) The Storm cycle brings high winds but no rain; except doubtfully to a few coast stations. This year 1888 is the first year on the records that Storm cycle rains have extended as far as Grahamstown. (Occurring with the sunspot minimum in 1877, the Storm cycle may have had something to do with the severe drought of 1877).

(5) The drought of the sunspot minimum is broken by a "mitigation" reaching the proportions of two, or even three, years of good heavy rainfall. As in the case of western rainfalls these "mitigation" rains occur at regular intervals of 12½ years. Three of these cyclical mitigations appear on the Grahamstown meteorological records. All three are identical with the mitigation years on the Cape Town cyclical diagram, allowing for a few months difference in 1855. Geo. Thompson "Travel and Adventures in South Africa, 1827" speaks of the uncertainty of the climate in the Eastern Province. A study of the various cyclical diagrams shows, that although the cyclical variation is constant for each locality, and although the same cycles run through all eastern rainfalls, the contrast between droughts and good seasons becomes sharper the more eastward one travels.

King William's Town.—Elevation 1,300 feet, 27 miles inland. The rainfall of King William's Town is less

GRAHAMSTOWN ELEVATION, 1,800 FEET, 27 MILES FROM SEA.

Year.	Rain. inches	Cycle.	Interpolations.
1851	25·46		
1852	22·14	Lag rain of sunspot max.	
		Here there is a break of two years.	
1855	32.04	Mitigation cycle.	
1856	33·27		
1857	30.99		
1858	26·08		
		Here there is a break of six years.	
1865	22·75		For Jan. an average month.
1866	23·26		For Nov. and Dec. from King William's Town.
1867	39·53	Mitigation cycle.	Do. Jan. to July do.
1868	30·43		
1869	24·25		
1870	29·97		Do. June to Dec. do.
1871	30·82		Whole year from King William's Town.
1872	39·65	Max. sunspots.	
1873	23·85		For Dec. from King William's Town.
1874	40·82	Lag rain of sunspot max.	
1975	20·18		
1876	27·57		
1877	14·29		April to Oct. from King William's Town and Alice.
1878	19·38		
1879	29·91		
1880	36·61	Mitigation cycle.	
1881	33·28		
1882	25 35		
1883	21·56	Max. sunspots.	
1884	26·00		
1885	31·78	Lag rain of sunspot max. Drought broke up end of 1885.	
1886	42·52		
1887	29·30		
1888	35·46	Storm cycle.	
Sum	698·52	(Omitting fragmentary records before 1865).	
Mean of 24 yrs	29·11		

regular than that of Grahamstown. The curiously heavy rainfall in 1876, cannot be regarded otherwise that as a prolongation of the lag rain of the sunspot maximum period. At other eastern stations the break in 1875 is slight or non-existent. In the drought of the minimum

KING WILLIAM'S TOWN.

Year.	Rain.	Cycle.	Interpolations.
1868	31·08	Year after cyclical mitigation	
1869	23·41		
1870	27·85		
1871	27·52		
1872	30·01	Sunspot max.	
1873	21·22		
1874	37 12	Lag rain of sunspot max.	
1875	22·76		
1876	37 26		
1877	12·18		August to Dec., Lovedale less 25 per cent.
1878	17·88		Jan. & Feb. from Grahamstown monthly averages.
1879	24·08		
1880	24·92	Cyclical mitigation.	
1881	24·72		
1882	23·67		
1883	15·95	Sunspot max.	
1884	16·48		
*1885	20 07	Lag rain of sunspot max.	
1886	30·02		
1887	25·93		
1888	21·59		
Sum	515·72		
Mean of 21 yrs.	24·56		

* Drought broke up Spring (end) of 1885.

period, and the rainfall of the maximum period, there is a general retardation of two, and sometimes nearly three years in the King William's Town as in other eastern rainfalls. Thus the drought of the last minimum sunspot period extended from 1877 to nearly the end of 1885.

THE LAST DROUGHT.

Altogether this drought is one of the severest that have occurred in recent years in South Africa. It began with the Karoo-like rainfall of 12·18 inches in 1877. The mitigation, though it lasted for the considerable length of 4 years, barely at its best reached the mean rainfall in 1880. The drought broke up in the Spring (at the end) of 1885. The rainfall returns being made up in calendar, instead of in seasonal years, this does not appear on the yearly returns of rainfall. The two worst calendar years of drought were in 1877 and 1878. These years fall at the exact sunspot minimum, and also at a time when the Storm cycle of the Atlantic rainfall was bringing deluges of rain to Cape Town. This last eastern drought we can all remember but too well. The planted trees about King William's Town, still shew the effects of the drought in their stagg-headed tops. The Katberg forest had been opened and injured by irregular working. Towards the end of the drought in 1884, there was a general dying out of the Black Ironwood trees (*Olea laurifolea.*) The disappearance of springs, the general deterioration of pasture, the losses in live-stock, the repeated failure of crops, and the ever increasing destitution among the poorer classes, can only be mentioned here. Practically, during the four calamitous years, 1877-8, 1883-4, we had an irruption of the Karoo climate into the fertile eastern country ; such a fact gives colour to the popular belief that the climate was changing owing to forest destruction, and the denudation of tree growth in the scrubby and open country. It is a terrible thing when in an agricultural country like British Kaffraria there are, in 7 years, 4 years of a climate only fit for the pastoral pursuits of the Karoo ! The drought broke up with the lag rain of the sunspot maximum thus :—

1883.—Sunspot maximum. Drought less severe at Aliwal and stations to north-east.

1884.—Drought rather less severe generally, and broken at Cathcart, Kei Road, and East London, i.e., at points of easiest precipitation of south-east rain clouds.

1885.—Lag rain of sunspot maximum. The Spring rains (at the end) of this year caused the general break up of the drought everywhere.

GOOD RAINS AT KING WILLIAM'S TOWN.

These, as we have seen, follow the sunspot cycle with a retardation or lag of two and sometimes of nearly three years. The rainfall of 1868 is probably referable to the mitigation cycle of the previous year; and the curious 1876 rain can hardly be regarded otherwise than as the continuance of the lag rain. But it may be worth noting that these two years of heavy rainfall 1868 and 1876, precede by a year the deluges of the Storm cycle at Cape Town in 1869 and 1877. The year 1868 is the year of heaviest rainfall (but one) on my Mauritius record. Probably there is here no real connection with the western Storm cycle; but it is tantalizing to have to work with meteorological records so short as are those in the east of Cape Colony. A continual difficulty in scanning yearly returns for eastern rainfalls is that they refer to summer rainfalls; and thus the return for each calendar year is the often discordant halves of two seasons separated by the winter drought which usually extends (with a break in July) from May to September. I hope in a separate paper to show the curves of the eastern and Natal rainfalls plotted by seasons.

Aliwal.—Elevation 4,400 feet, 167 miles inland. Of the rainfall records in South Africa extending back for 20 years and above, Aliwal North is the only station exhibiting, at first sight, serious anomalies, when its rainfall curves are plotted and compared with the sunspot and secondary cycles. Aliwal lies at the high elevation of 4,400 feet, and its rainfall must be necessarily modified by the barrier of the lofty Drakensberg mountains (highest peaks close on 10,000 ft.) over which the rain clouds from the Indian Ocean have to pass. That these anomalies are local, I convinced myself by examining the break up of the last drought. This happened only three years ago, and we have rainfall returns from a number of stations near Aliwal. In the case of these the drought broke up, as everywhere else in the east, with the lag rain of the sunspot maximum in 1885 and

1886. But in Aliwal the drought did not finally break up until 1887—*vide* cyclical diagram. Exactly the same thing happened at the same period of the preceding cycle in 1876. Again, the cyclical diagram shows the rainfall of the sunspot maximum to be early and abundant, almost equally so in both of the cycles for which we have figures. It appears, therefore, that the local effect of situation at

INLAND EASTERN RAINFALL,—ALIWAL.

Year.	Rain. inches.	Cycle.	Interpolations.
1866	21·70		For Jan. and Feb. average months interpolated.
1867	18 91	Mitigation cycle.	
1868	26·68		
1869	19·93		
1870	28·70		
1871	31·93		
1872	28·69	Sunspot Max.	
1873	24·30		
1874	24·40	Lag rain of sunspot max.	
1875	24·93		
1876	30·67		
1877	17·00		
1878	23·96		
1879	22·86		
1880	28·64	Mitigation cycle.	
1881	24·91		
1882	29·60		Nov. and Dec. from Dordrecht with the average monthly correction applied
1883	21·88	Sunspot max.	
1884	18·36		
1885	22·44	Lag rain of sunspot max.	
1886	19·87		
1887	29·12		
1888	22·54		
Sum	562·02		
Mean of 23 yrs	24·44		

Aliwal is (*a*) to hasten and increase the volume of the rain of the sunspot maximum; (*b*) to defer and diminish the lag rain of the sunspot maximum.

Thus viewed, the cycles of rainfall at Aliwal become both simple and regular. So far as conclusions may be drawn from two cycles only, the droughts at Aliwal shew these features:—They have been severe but short and broken by the cyclical mitigations. We cannot say what will happen when the cyclical mitigation fails—as it will fail after the ~~present~~ cycle (for two cycles)—to fall during the drought of the sunspot minimum.

The meteorological Commission has now rain guages at Basutoland, among the Drakensberg mountains, and at several other mountain stations, as high as, and higher than, Aliwal North. The returns from these stations and the further development of the Aliwal figures, will open up an interesting field of enquiry; perhaps giving an insight into the movements of, and precipitation from, the upper clouds of the south-east trade wind; and affording a confirmation or confutation of my suggested explanation of the phenomenon of "retardation" or "lag."

METEOROLOGICAL RECORDS—NATAL.

From the Colony of Natal the meteorological records are shorter and scantier than those from Cape Colony. The following are the best:—

Coast { Durban with 20 years, including 1888.
Ottawa with 18 years, including 1888.

Inland { Gardens Cliffe, with 22 years, including 1888.
Maritzburg, with 17 years, including 1888.

The Maritzburg observations ceased in 1867, and have only been resumed recently, bnt the year before they ceased, a good series began at a neighbouring station, Gardens Cliffe: Maritzburg, elevation, 2,100 feet; Gardens Cliffe, elevation, 2,270 feet. I have therefore combined ~~these two stations into one good series. The mean of the~~ Maritzburg observations is 34·45 inches. The mean of the Garden's Cliffe observations is 37·17 inches.

The Durban records show 2 detached years, then 2 consecutive years, 1866-7, followed by a gap of 5 years, and then continuous observations. Of the 5 years gap, 3 years can be satisfactorily supplied from the similarly situated coast station of Ottawa, using 1·1 as a factor. This figure represents the difference between Ottawa and Durban during those years, when there are records from both stations. The remaining 2 years are supplied, not so satisfactorily, from the Maritzburg rainfall using a similarly obtained factor (which happens to be almost the same).

COAST RAINFALL INDIAN OCEAN.—DURBAN, NATAL

Year.	Rain. inches.	Cycle.	Interpolations.
1866	48·54		
1867	33·08	Cyclical mitigation.	
1868	48·80		Whole year Gardens Cliffe × 1·1 : bad.
1869	33·91		Do. do. bad.
1870	38·36		Do. Ottawa × 1·1 good.
1871	39·84		Do. do. good.
1872	62·38	Sunspot max.	Do. do. good.
1873	42·22		
1874	53·80	Lag rains.	
1875	54·78		
1876	35·22		
1877	35·65		
1878	28·24		
1879	44·46		
1880	47·63	Cyclical mitigation.	
1881	37·08		
1882	36·21		
1883	44·52	Sunspot max.	
1884	44·56		
1885	34·49	Lag rains.	
1889	31·79		
1887	31·87		
1888	37·74		
Sum	721·88	Actual rainfall only.	
Mean of 18 yrs	40·10		

Note.—In 1851, the rainfall was 41”.91 inches.
In 1855, the rainfall was 82”.82 inches.

The year 1855 is the cyclical mitigation, and as such the rain was heavy all over the east, but this extraordinary fall of 82·82 in. was probably the apex of the cliptical path of a tropical cyclone; it did not penetrate far inland, the rainfall at Maritzburg being below what might have been expected from the heavy rains of the preceding and following mitigation rains.

Looking at the Natal figures of rainfall and the cyclical diagrams, we see that, as was the case with the Atlantic rainfall, the cyclical variation is more regular near the coast than inland. The Durban rainfall so far as can be judged from two sunspot cycles, shows the following :—

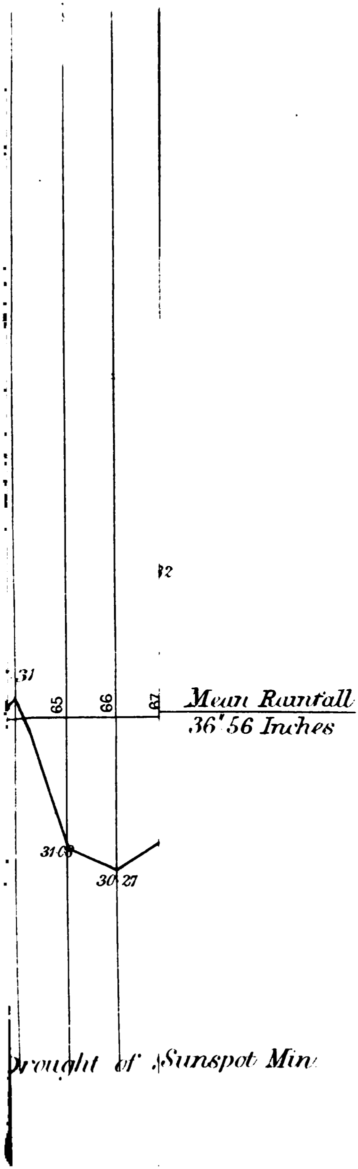
Sunspot Max :—Rains strong and punctual in both cycles.
Mitigation Rains :—Strong and regular in both cycles
Lag Rains :—Strong and punctual first cycle, late second cycle.

The Maritzburg Gardens-Cliffe Series exhibits curves following very closely the Grahamstown curves. In both the sunspot maximum period is feeble or absent, the lag rain of the sunspot maximum strongly marked. Further, the Maritzburg Gardens-Cliffe Series brings out more clearly that noticeable feature in the Grahamstown curves which, from its slight character in the Cape Western rainfall, we have spoken of as the "mitigation" in the droughts of the sunspot minimum. In all rainfalls coming from the Indian Ocean this mitigation is a most important feature. Turning to the cyclical diagram of rainfall at the Royal Observatory, page 79, the mitigation rain of the drought of the sunspot minimum will be seen to occur at the following years :—

1842.
1855.
1867.
1880.—Anticipated by the stronger Storm cycle.

In 1880 the drought of the minimum sunspot period was so broken by the interference of the powerful Storm cycle, that the mitigation, a very slight feature in Atlantic rainfalls, is not observable. But at Uitenhage 1880 is the year of heaviest rainfall on the record; and at all stations, getting

AM : M


31
65
66
67
Mean Rainfall
36'56 Inches
31·09
30·27
rought of Sunspot Min

INLAND RAINFALL.—INDIAN OCEAN, MARITZBURG AND GARDENS-CLIFFE SERIES (NATAL).

Maritzburg : Elevation, 2,100 feet ; Distance from sea 41 miles.

Year.	Rain. inches.	Cycle.	Interpolations
1854	50·56		
1855	42·77	Cyclical mitigation.	
1856	50·98		
1857			
1858	27·42		
1859	28·40		
1860	30·60		
1861	22·41	Sunspot max.	
1862	29·97		
1863	34·66	Lag rains.	
1864	37·31		
1865	31·08		
1866	30·27		
1867	31·49		
1868	44·36	Cyclical mitigation.	
1869	30 83		Here begin the Gardens-Cliffe observations.
1870	30·63		
1871	32·26		
1872	44·98	Sunspot max.	
1873	36·50		
1874	45·60	Lag rains.	
1875	37·08		
1876	38·52		
1877	33·91		
1878	26·72		
1879	42·29		
1880	46·18	Cyclical mitigation.	
1881	37·62		
1882	39·25		
1883	37·49	Sunspot max.	
1884	38·33		
1885	33·70	Lag rains.	Maritzburg.
1886	34 68		Do.
1887	*42·56		Do.
1888	41·82		Do.
Sum	1243·23		
Mean of 34 yrs	36·56		

* Season 1886—87.

their rainfall from the Indian Ocean (allowing for the calendar division of the rainy season), the above four years are years of heavy rainfall, rivalling and sometimes surpassing, the regular sunspot rains. Till the forest guages were established on the Amatola mountains, by far the heaviest recorded rainfall in South Africa was 82·8 inches at Durban in 1855, a mitigation year. Inland, the Maritzburg register shows heavy rainfall for the three years, 1854-5-6. Turning to the cyclical diagrams for Durban, for Maritzburg Gardens-Cliffe, and for Grahamstown, we see the next two "mitigation" years 1867 and 1880 are represented by years of heavy rainfall (1867 in Grahamstown and 1868 in Natal; the apparent difference of a year being probably a few months in reality, owing to the calendar year cutting one season's rainfall into two halves).

Thus these "mitigation" years 1842, 1855, 1867 and 1880 resolve themselves into a secondary cycle with a probable period of 12·5 years. Heavy, or very heavy rain, in 1892-3, extending to inland stations, will establish such a cycle on a firm basis; and correct or confirm the assumed period of 12·5 years. Moderately heavy rains not extending inland in 1894 or the end of 1893, will be the regular rains of the sunspot maximum and will prove or disprove nothing, as regards this secondary cycle. In the Atlantic rainfall for 1850 when the maxima of the Sunspot and Storm cycles coincided, the resultant rainfall, had the character of that of the sunspot maximum. As the bulk of South Africa is watered by rain, brought by the south-east trade wind of the summer months (December, January, and February), the further investigation of this 12·5 years secondary cycle is clearly very important. Probably the rainfall registers of Mauritius (which I hope to obtain shortly) will throw light on this subject; as the rainfall registers of New Zealand, and the southern and western portions of Australia, should repeat the 9·5 years secondary cycle in the Atlantic rainfall of the winter season of Cape Colony. 100 being an exact multiple (8) of 12·5, it follows that the mitigation years are the same in every century. They are for the present century, (omitting the fraction 0·5), 1805, 1817, 1830, 1842, 1855, 1867, 1880, 1892, 1905, and so on. In this respect the mitigation cycle resembles the Wolfian cycle; 100 being an exact multiple (9) of the sunspot cycle of 11·11 years.

In the early years of the Maritzburg rainfall there is the notable feature of an abnormally wet period, being followed by an abnormally dry period, all the cycles in these two periods partaking of the character of the period. The years 1854-5-6—" Mitigation " years—represent a period of abnormal and long continued excessive wet. This wet period extended over the eastern side of the continent In 1854 there were terrible floods and rains in the Eastern Province of Cape Colony. The sufferings of the English settlers of that year in Albany are historical. For 1857 the Maritzburg record is wanting; but from 1858 to 1864, we have a curious droughty period—the swing back of the pendulum. In the rainfall curves of this droughty period, we see the two epochs, the sunspot maximum and the lag rain of the sunspot maximum clearly enough, but both very low down on the scale. The lag rain of the sunspot maximum is the most powerful and the only certain epoch for rain in eastern rainfalls away from the immediate coast-line ; but in 1864 this brought the rainfall barely above the average. In eastern rainfalls there is usually one year's drought between the rain of the sunspot maximum and the lag rain of the sunspot maximum. In 1861 this produced the severe drought of 22 inches at Maritzburg. In fact, modified by the cycles, we see in the early years of the Maritzburg records an exemplification of the old law of averages, that an abnormally wet period is followed by an abnormally dry period or *vice versa*.

APPROXIMATE FORECAST FOR EASTERN SEASONS.

The eastern rainfall differs primarily from the Atlantic rainfall, in being influenced by the Storm cycle only in the matter of wind. As regards rain, the secondary Storm cycle of Atlantic rainfalls, is replaced, in Indian Ocean rainfalls, by the secondary Mitigation cycle. In the primary Sunspot cycle we have rain (*a*) at the exact maximum of the Wolfian cyle ; (*b*) the lag rain two years afterwards. The first cannot always be depended upon even for coast or mountain stations; and at 20 miles inland it fails two seasons out of three. It disappears altogether from the Karoo cyclical diagrams. On the other hand, the lag rains of the sunspot maximum are uncertain along the coast line, but they bring the greatest bulk of rainfall to the continent of South Africa.

Droughts occur at any time between these cyclical rain periods; their severity and position in the sunspot cycle depending on the incidence of the mitigation rains. These mitigation rains seem to be connected with similar years at Mauritius and Australian stations. Possibly they have something to do with the cyclones of the Indian Ocean. I hope to study the subject further. In the meantime the following may serve as an approximate forecast. (Pages 109 & 110.)

This forecast does not lay claim to the exactness of that for Atlantic rainfalls. It is founded on shorter meteorological records, and Indian Ocean rainfalls are less regular than Atlantic rainfalls. Further, after the current Sunspot cycle a change will supervene of which one cannot foresee the exact consequences. In 1855, the Mitigation cycle coincided with the sunspot minimum; and up to date the cyclical mitigation has fallen within the drought period of the sunspot minimum. In 1905, the Mitigation cycle will coincide with the sunspot max. Thus, in the forecast, we have a juxtaposition of the cycles that has not occurred during the short meteorological records. We may assume that one of two things will then happen:—

(a.) The drought will be very severe.

(b.) There will be irregular non-cyclical mitigations.

In the Uitenhage and Graaff-Reinet cyclical diagrams, three mitigation rains are seen, of which two are cyclical and one irregular. The latter is barely traceable outside the Karoo—including Uitenhage. In the Cape Town cylical diagram there is one small irregular mitigation in 1852; the other mitigations are cyclical. I have not yet been able to gather sufficient information about ihe historical rains of 1822 to decide whether they are referable to an irregular mitigation or to a coastwise extension of

INDIAN OCEAN RAINFALL

South Africa, except Southern and Western Coasts.

FORECAST OF EASTERN SEASONS

For the Period 1888 to 1920.

YEAR.	Sunspot Cycle 11·11 yrs.	Storm Cycle 9·5 years	Mitiga-t'n. cycle 12·5 yrs.	FORECAST.
1889	Min.			Drought.
1890				Drought.
1891				Drought or moderate rain.
1892			Max.	Rainfall good to heavy.
1893				Drought or moderate rains.
1894	Max.			Drought at inland stations. Dronght or good rains at coast and mountain stations.
1895				Drought at most stations, including those with good rains last year. But at coast and mountain stations where drought prevailed last year, it will be breaking this year.
1896	Lag			A general break-up of the drought.
1897		Max.		Good rains, general during the summer, but possibly local floods or droughts ; a stormy winter.
1898				Good or moderate rains, with drought at some stations.
1899				Drought With an irregular mitigation of one or two years, good or average rainfall occurring most probably about 1901. The mitigation is uncertain and the drought may be very severe at some stations.
1900	Min.			Drought
1901				Drought
1902				Drought
1903				Drought
1904				Drought or moderate rains.
1905	Max.		Max.	Most probably general good rains ; there is no precedent in the meteorological records for these two cycles coinciding.
1906				Probably good rains with drought at a few stations.
1907	Lag	Max.		General heavy rains and storms.
1908				Rainfall good or moderate.

FORECAST.—*(Continued).*

YEAR.	Sunspot Cyle 11·11 yrs	Storm Cycle 9·5 years	Mitiga-t'n. cycle 12·5 yrs.	FORECAST.
1909				Rainfall still good at many stations drought at others.
1910				Drought With an irregular mitigation of one or two years good or average rainfall occurring most probably about 1912. The mitigation is uncertain and the drought may be very severe at some stations.
1911	Min.			Drought
1912				Drought
1913				Drought
1914				Drought
1915				Drought or moderate rains.
1916	Max.	Max.		Drought broken at most stations. A season similar to 1850.
1917			Max.	Good rains, general—if the rainfall in 1892 confirms the 12·5 year cycle.
1918	Lag			Heavy rains general, excepting a few coast stations.
1919				Good seasons continue.
1920				Fair seasons with drought at a few stations.

the Storm cycle rains. On the whole, the balance of probability seems in favour of irregular mitigation rains when the cyclical mitigation fails, The probable position of these mitigations, it will be observed, has been noted in the forecast.

For a high-lying station such as Aliwal, with special cyclical features of its own, a special forecast founded on its cyclical diagram is necessary. The same remark applies in a greater or less degree, to every station, or group of stations. For the Eastern Karoo, a small special forecast, founded on the admirable Graaff-Reinet records, was given at page 91. I have drawn the cyclical diagrams for all stations possessing meteorological records for 20 years *i.e.* for nearly two sunspot cycles; and it is on these cyclical diagrams that the above general forecast for Indian Ocean rainfalls is founded. The difference in the relative values of the two secondary cycles must not be forgotten

The Mitigation cycle, a prominent feature in Indian Ocean rainfalls, requires confirmation; while the Storm cycle, the most prominent feature in Atlantic rainfalls, is thoroughly established.

CYCLES OF CAPE WEATHER AT MAURITIUS.

During a short holiday at Cape Town, I was able to procure the Port Louis rainfall from 1853 to 1871. For these years, it will be observed, that all the features of the Cape rainfall are repeated; the main difference between the Mauritius and Cape rainfalls consisting in the fact

Year.	Rainfall at Port Louis, Mauritius.	Connection with the sunspot and secondary cycles of the Cape rainfall.
1853	39·83	Drought of the Min. Sunspot period.
1854	39·44	
1855	42·67	Cyclical mitigation of drought ; see cyclical diagram of Cape rainfall.
1856	46·23	
1857	43·45	
1858	35·51	Drought of the Min. Sunspot period.
1859	56·88	Rainfall of Storm cycle same year at Cape.
1860	45·17	Rainfall of sunspot max., one year later at Cape, Mauritius being nearer the Equator.
1861	68·73	
1862	28·40	Early drought of sunspot min., Cape 1 year later ; compare with famines at Madras, preceeding min. sunspots by a year.
1863	33·42	
1864	24·15	
1865	44·73	Irregular mitigation of drought at the middle, Cape 1867—cyclical.
1866	20·57	Drought of min. sunspot period.
1867	35·97	
1868	64·18	*(a.)* Rainfall of storm cycle 1869—70 at Cape, where features are repeated.
1869	54·58	
1870	45·58	(*b.*) Rainfall of the max. sunspot period 1872, at Cape.
1871	44·61	
Sum	814·10	
Mean of 19 yrs.	42·85	

that Mauritius being tropical, the rainfall and drought of the sunspot cycle are between one and two years earlier.

What is of great interest is the appearance of the Cape Storm cycle in the Mauritian rainfall. In 1859, it is the same year as at Cape Town. In 1869, a merging of the Sunspot and Storm cycles in the heavy rainfall period 1868—70 at Mauritius, makes it possible that 1869 is the year of Storm cycle at Mauritius, as at the Cape. But, comparing the features of the rainfall at the Cape, 1869—70, with Mauritius, 1868—69, it seems more probable that the Storm cycle at Mauritius precedes that of the Cape by a year, or by six months taking the mean of the two cycles of records. This heavy rain of 1868 at Mauritius, extended to Natal, and to Cape Colony as far west as Uitenhage.

The earliness of the sunspot rainfall at Mauritius merges *(a.)* and *(b.)* into one rainfall period. At the Cape they are separated by the one droughty year 1871. The cycles being nearly the same at Mauritius and at Cape Town, but the rainfall at Mauritius preceeding that of Cape Town by a year, it will be an interesting study to determine how far the special features of each cyclical period at Cape Town can be deduced from the preceeding year's rainfall at Mauritius. This I hope to investigate at an early date.

CYCLES OF CAPE WEATHER IN AUSRALIA.

Our cycles of Cape weather may be traced in the following two fragments of Australian rainfalls, all that are at present in my possession :—

Year.	Rainfall at Adelaide, Australia.	Connection with the cycles of an Eastern station, Cape Colony.
1839	19·84	One year's drought as in Eastern rainfalls, South Africa.
1840	24·11	Lag-rain of sunspot max.; corresponds exactly with Eastern climate of South Africa.
1841	17·96	Drought of sunspot min. with cyclical mitigation in 1842, the same as in South Africa, and an irregular mitigation in 1846—47, just traceable on the cyclical diagram for Cape Town.
1842	20·32	
1843	17·19	
1844	16·88	
1845	18·83	
1846	26·89	
1847	27·61	
1848	19·74	
1849	25·44	Rainfall of sunspot max.
1850	19·27	One year's drought as in Eastern rainfall South Africa.
1851	30·63	Lag-rain of sunspot max. with two or three good years following: corresponds exactly with Eastern climate of South Africa
1852	27·34	
1853	26·99	
1854	15·36	Retarded drought of sunspot min. with cyclical mitigation 1855—56, corresponding exactly with Eastern climate of South Africa.
1855	23·15	
1856	24·92	
1857	21·16	
1858	21·52	
1859	14·84	
1860	19·67	
Sum	479·66	
Mean of 22 yrs.	21·8	

This fragment of the meteorological records from Adelaide, follows so closely the cycles of an Eastern station near the coast in South Africa, that I have no hesitation in predicting that an extended examination of Australian stations, will show a cyclical variation of climate almost identical with that of of South Africa. Looking over these Australian figures again, I find it hard to believe that they are not South African, the cyclical analogy is so perfect.

I have yet another fragment of Australian rainfall that of Brisbane from 1860 to 1871 :—

Year.	Rainfall at Brisbane	Connection with the Cycles of the Cape Rainfall.
1860	54·63	Storm cycle ?
1861	69·44	Rainfall of sunspot max.
1862	28·27	One year's drought, as at eastern stations of South Africa.
1863	68·82	Lag rain of sunspot max. identical with South Africa, east.
1864	47·00	Rapid decline of lag rain as in Cape Colony ; *vide* cyclical diagrams for Graaff-Reinet and Uitenhage.
1865	24·11	Drought of min. sunspots with cyclical mitigation years the same as in South Africa (east), *vide* cycle diagrams for Grahamstown, King William's Town, and Maritzburg.
1866	37·24	
1867	61·04	
1868	35·98	
1869	54·36	Rainfall of Storm cycle, same as at Cape, except that there the first year had the greater rainfall.
1870	79·06	
1871	45·45	
Sum	605·40	
Mean of 12 yrs.	50·45	

Here again we have a cyclical variation repeating the cycles of weather in South Africa. If it is just to draw conclusions from such a fragment, the climate of Brisbane differs from that of any South African station yet examined only in that it exhibits, in one locality, the lag rain of the east, and the Storm cycle of the west, of South Africa The short meteorological records of the inland western station of Ceres, Cape Colony, come very near doing this.

To resume ; the cycles of the Cape seasons are repeated in the weather at Mauritius, and at Adelaide and Brisbane in Australia. The cycles of the Mauritius weather precede the Cape by one year (and a fraction plus or minus, according as the calendar year cuts the summer rainfall.) The sunspot maximum rain of the two Australian stations coincides with, or is slightly more punctual than, the sunspot maximum rain in South Africa. The droughts are the same; and the mitigation years are, with one exception, cyclical, and identical with those of South Africa. The Storm cycle seems clearly indicated on the Mauritius records ; it appears once on the Australian registers—doubtfully twice, and then at the sub-tropical station of Brisbane.

REMARKABLE SEASONS.

I must begin the statistics of remarkable seasons by going over a list furnished me from the recollections of three gentlemen who have a long and intimate acquaintance with the eastern climate of Cape Colony—the Hon. C. Brownlee, the Rev. W. R. Thomson, and the Rev. R. Birt. In my King William's Town lecture there is shown the correspondence that exists between this list and sunspots as actually observed. The closer correspondence that exists, between this list, and the Wolfian sunspot and secondary cycles, is now exhibited.

Brownlee, Thomson, and Birt's List of Remarkable Seasons in the East of the Colony.

1822. FLOODS BREAKING UP SEVERE DROUGHT.—Gamble's catalogue shows that this happened towards the end of 1822. Both the drought and floods were very remarkable and will be found frequently referred to in Cape histories. 1822 was the exact year of minimum sunspots, a period at which one of the irregular mitigation rains might be expected. In eastern rainfalls—*vide* cyclical diagrams for Grahamstown, King William's Town, and other stations—mitigation rains vary from moderate to excessive. Further, a reference to the sixth remarkable season on Gamble's list shows that the winter of 1822 was a remarkable season in the west caused by the Storm cycle; so that the Albany floods of 1822 were probably "mitigation" rains reinforced by the Storm cycle. Further research may show these floods to be simply an extension of the western Storm cycle rains.

Irregular mitigation or Storm cycle.

1828. FLOODS IN BUFFALO.—1827·2 was the maximum of the Wolfian cycle, so that if floods came early in 1828, as is probable, they were punctual to a month. In any case they occurred within a

Sunspot max. Wolfian cycle.

fraction of a year of the sunspot maximum of the Wolfian Cycle. Heavy rain at the sunspot maximum is rare or confined to coast stations on the eastern side of South Africa.

1841-42. Cyclical mitigation. RAIN BREAKING UP DROUGHT.—A more particular account of this drought and rain, with their cyclical explanation, will be found in Gamble's catalogue—No. 9, page 126.

1848. Irregular mitigation rain probably influenced by early strong max. of observed spots. FLOODS, EASTERN RIVERS, MARCH, 1848.—This coincides with no cycle and is one of the irregular mitigation rains we see on the cyclical diagrams of eastern stations. It may be worth noting, however, that these floods coincided with an observed early strong maximum of spots—100·4 spots on Wolf's list.

1863. Lag rain. FLOODS, EASTERN RIVERS, AND HEAVY RAIN: Described also in Brown's Hydrology of South Africa. The regular lag rain of eastern stations.

1874. Lag rain. HEAVY RAIN AND FLOODS AT CLOSE OF YEAR.—The regular lag rain of eastern stations.

1885. Lag rain. HEAVY RAIN AT CLOSE OF YEAR, BREAKING UP SEVERE DROUGHT.—The regular lag rain of eastern stations.

Thus, the recollections of these three gentlemen confirm what was noticed in studying the cyclical diagrams of eastern stations; namely, that the lag rain is the most important feature in the rainfall of eastern stations. During the last three sunspot cycles it has come punctually almost to a month.

And this is what the three wise men of the east tell us has happened during the last sixty-six years! Of seven periods of floods and heavy rain there were:

Lag rains	3
Sunspot max. (Wolfian cycle)...	1
Sunspot max. (Observed spots)	1
Sunspot min. (Irregular mitigation rain, or Storm cycle).	1
Cyclical mitigation	1

The Storm Cycle and Wrecks.

The rain brought by the 9½ year Storm cycle appears very clearly on the cyclical diagram for the Royal Observatory, Cape Town. But it is purely Atlantic rainfall extending uncertainly along the soutnern coast. The following cutting from the *Cape Argus* of February 20th, 1889, describes the heavy rains of the Storm Cycle on the Atlantic coast :—

NAMAQUALAND.

(*From a Correspondent*).

February 7th, 1889.

"Great was the anxiety felt by the Boers during the winter of 1888, for such rains have not fallen, it is said, *since 1822.* Rivers which have not had water in them *for nine years past* ran last winter for six months, and were frequently impassable. Much of the young crop was so long under water that it was feared it would perish. In a few places such was the case ; mostly on the Kamiesberg."

Here are references to two Storm cycles—the previous cycle, and 1822. For a further reference to the floods of 1822 *vide* below Gamble's catalogue.

The violent storms of the 9½ year cycle necessarily bring some rain to eastern stations, but the rain seems to be uncertain and generally not to extend more than a few miles from the coast line. Once, as we have seen during the last half century, in 1822, general floods are referable doubtfully to the Storm cycle. But an inspection of the cyclical diagrams for eastern stations affords no evidence that the Storm cycle has any influence on eastern rainfalls ; and, generally, the character of the Storm cycle is deluges of winter rain to western stations ; terrific winds elsewhere in South Africa. While the Storm cycle rain was floodingCape Town (this past year 1888), the newspapers from other parts of the Colony were full of accounts of the violen ce of the wind. At King William's Town, on the evening of the 23rd May, the town presented the appearance of having been bombarded. Gables were blown in, verandahs unroofed, and the streets strewn with the limbs of trees. These terrific winds lasted for a week. At the foot of the Amatola mountains I, as one of a party of forest officers, witnessed a heavy full-sized wagon loaded with wood blown over bodily. A fortnight later we experienced a renewal of these fearful winds in the Katberg mountains. There the people said such winds had not been known *for the last nine or ten years.* They occurred again at intervals during the winter of 1888. Wind pressure guages and anemometers are not the most satisfactory meteorological instruments ; and yet these seemed to afford the only chance of tracing back the Storm cycle at eastern stations. Nor did the broken anemometric records from eastern stations hold out much promise of a reward for study ; but my collection of remarkable seasons has given me a rich return in establishing a cycle for colonial wrecks, and this cycle identical with the Storm cycle of the western rainfall !

The following "Wreck Record" cut from a Port Elizabeth newspaper shows how gales, causing wrecks along the southern coast, correspond with the years of very heavy rainfall at Cape Town, marking the cycle of 9·5 years that I have termed the Storm cycle. It is of course the south-easters that bring ships ashore at Port Elizabeth. This is the second half of the cyclonic storm, of which a northerly wind, or the nor'-wester, is usually the first half :—

PORT ELIZABETH : WRECK RECORD.

"On the 16th October, *1859*, there were 8 vessels at anchor in Algoa Bay, when a heavy gale from the south-east drove six ashore ; the two escaping were the Meg Merilees, and Sarah Black.

"At Algoa Bay, on the 19th September, *1869*, very terrific weather was experienced. At the time there were 14 vessels riding at anchor in the roadstead. On the following morning 12 had gone ashore, and two only escaped.

"On Monday last there were 11 vessels at anchor in Algoa Bay, whereas to day (30th August, *1888*) there are only two, viz., the Tweed, and Burgomeister Schorer."

Turning to the diagram of cycles of rainfall at the Royal Observatory, Cape Town, it will be seen that these years, 1859, 1869, and 1888, are all the exact years of the Storm cycle rainfall at Cape Town.

There remains the Storm cycle year 1878 on the Cape Town cyclical diagram. In 1878 the casualties though heavy were less at Algoa Bay than during the previous or following Storm cycle years, but fearful gales were experienced that year off the coast of South Africa from the 16th to 23rd July, 1878. On July 16th, two vessels came ashore at Port Elizabeth during the south-east gale. During the same gale two distressed vessels put into Port Elizabeth; a third was abandoned at sea. By the 18th, the wind had veered in the normal way to north-east, and then began the wrecks at Table Bay which are still remembered at Cape Town. These north-east gales lasted from the 18th to 23rd July, 1878; and produced 5 wrecks in or near Table Bay. These, and the following, particulars are taken from the article "Shipping Casualties" in the Cape Argus Directory for 1889. This list is of great interest, showing, as it does statistically, the exact influence of the Storm cycle years 1878 and 1888 on a decade of shipping disasters caused by stormy weather:—

CASUALTIES FROM GALES.

		Algoa Bay.	Elsewhere on Southern Coast.	Total.
Storm cycle year	1878	7	9	16
	1879	0	3 + 1?	3
	1880	4	6	10
	1881	2	3	5
	1882	0	2	2
	1883	1	3	4
	1884	1 + 1?	0	1
	1885	0	2	2
	1886	0	1	1
	1887	0	0	0
Storm cycle year	1888	10	9	19

The only other year in which there were casualties at all comparable to the Storm cycle years 1878 and 1888, was 1880 with a total of 10 wrecks. The year 1880 is a "mitigation" year on the secondary 12·5 year cycle. This is the only indication I have at present, that the secondary 12·5 year cycle shares the tempestuous character of the Storm cycle. While the rainfall of the sunspot maximum is due to increased evaporation; and thelag rains to delayed precipitation; it seems possible that the rainfall of the two secondary cycles may be due to an increased intensity of cyclonic disturbances. All the casualties at Port Elizabeth occurred, with one exception, during south-east gales; the great majority of those at East London and off the coast were also with south-east gales. Of the 10 wrecks at Algoa Bay in 1888, 9 occurred during the terrific south-east gale of August 30th and following day.

To Marine Insurance Companies at Port Elizabeth, and to a lesser extent all round the coast, my advice would be:— Look out for the nine-and-a-half year Storm cycle!

An account of the winter of 1652 is given in my King William's Town lecture, page 31. The rare phenomenon of snow on Table Mountain mentioned in 1652, occurred again this Storm cycle year 1888. Rain and weather such as is described, could only occur at the maximum spot period, or the Storm cycle period. The latter suits the description of the season far better; and furthermore, 1652 as a date, is two-and-a-half years after the maximum spot period 1649·4 The lag rains of the east of the Colony being unknown at Cape Town, we are forced to conclude that the stormy winter of 1652 was a Storm cycle year. The date when the Storm cycle first appears on the meteorological records of the Royal Observatory, Cape Town, is 1850. The difference between the two dates 1652 and 1850 is 198 years. This gives exactly 21 Storm cycles, if we assume the correct value of the cycle to be 9·43 years. This is a close approximation to the value 9·5 years derived from numerous but shorter modern data.

THE STORM CYCLE AND THE FIRES OF 1869 AT KNYSNA.

The year 1869 is one that will ever be remembered in the Knysna forest country. A fiery blast of hot wind passed through the whole district. It is estimated that one-third of the more accessible and worked forests were, burnt; and, amongst the farms and homesteads, Portland. the residence of the Hon. R. Barrington, and Mr. Darnel's, house near Knysna village. The sparks from the burning country were borne out to sea; and a schooner lying off the Knysna Heads, had to shorten sail, for fear of the sails taking fire. Fires seemed to spring up spontaneously all along the coast from George to Tzitzikama; and forest and veldt were swept away, with the rapidity of a jungle fire in India. Meteorologically what happened was this. From 1864 to 1869 was the drought of the min. sunspot period; then came the Storm cycle winds of 1869, *vide* cyclical diagram of rainfall at the Royal Observatory. With such a combination the hot "berg" wind of the Knysna country became as the simoom of the deserts of India. The tinder-like vegetation caught fire at various points; and, during that long day in February, while the "berg" wind lasted, nothing could stop the appalling destruction.

The Storm cycle is now approaching a confluence, with the sunspot max. After this is past, we shall again have the winds of the Storm cycle, following the drought of the sunspot min.; and then, in 1916, 1926, or 1935 there will be dangerous years for the Knysna forests—years in which the irregular worked forests will hardly escape. In 1869 it was chiefly the over-worked and irregularly worked forest that was burnt. The charred remains of the Katberg forests tell a similar tale.

GAMBLE'S CATALOGUE.

Among the printed papers of the South African Philosophical Society for 1885 is a catalogue of Meteorological references by J. G. Gamble, F.R. Met. Soc., to whom the Meteorology of this country is so largely indebted. Running the eye down these references, one cannot help perceiving how all the remakable seasons are connected with one or other of the Cycles we have been considering:—

REMARKABLE SEASONS.	CYCLES.
1. Backhouse, severe drought in Kaffraria 1842.	The regular drought of the sunspot min.—see below No. 9.

2. Jas. Chapman, F.R.G.S., speaks of exceptional rain in 1862—63 between Walwich Bay and Ngami, heavier rain than known by the oldest inhabitant.	Rainfall of sunspot max.: 1862 at Cape Town.
3. Exceptionally heavy rainfall at Natal, August 1868, and March, 1873. R. J. Mann, M.D. The same in "Proceedings of Royal Met. Soc," quoted separately in Gamble's Catalogue	Winter rain at Natal is remarkable. This is possibly connected with the rainfall of the Storm cycle 1869 at Cape Town, and the forests fires and rain at Knysna earlier in the same year. There was heavy rain in 1868, at Mauritius and Kaffraria. I hope to obtain meteorological records from Mauritius shortly and to study the ramifications of the Cape Storm cycle in the Indian Ocean and elsewhere. A reference to Meteorological records shows that the rain of March 1873 was not lasting: The year 1873 was one of average rainfall in Natal and drought generally in the east of Cape Colony ; so that the quotation probably refers to some of the early local rains heralding the general break up of the drought with the lag rains of 1874—vide discussion of break-up of drought in Kaffraria the following cycle page, 99.
4. Geo. Thompson: "No rain at Beaufort for three years before 1823." The Hartebeeste River had not run for 5 years.	The regular drought of the Sunspot min. It may be noted also that there was a late weak max. of sunspots in 1817, followed by a strong min. in 1823.
5. In a report, "State of Cape of Good Hope in 1822," published by Murray, London, 1823.	This reference was very puzzling till the discovery of the Storm cycle. The year 1822 is the

Excessive rain and storms in July 1822, about the Cape: drought in Albany.	exact year of min. sunspots, and should show drought or light mitigation rains in the west; but if the Storm cycle is reckoned back in cycles of 9·5 years from 1850 (its first appearance on the records of the Royal Observatory), it will be seen that we get to 1822. Thus, 1850, 1840.5, 1831, 1822·5= year beginning July 1st, 1822. This fact is doubly interesting, as explaining the reference, and strengthening the newly discovered secondary cycle.
6. In proceedings of Royal Geo. Society, Selous writing 21 years later speaks of drought at Lake Ngami and unprecedented low water in the River Botlelle in 1879—"It failed for the first time to reach the gardens of the Makalakas."	The regular drought of the Sunspot Min. This drought was perhaps intensified by a prolonged minimum of observed Sunspots lasting from 1875 to 1879. In 1878 the record drops to 3·4 sunspots. It may be added that 1878 was the year of the Storm cycle, but Lake Ngami has a summer rainfall from the Indian Ocean, and would thus experience the drought of the Sunspot Min. unbroken by the Atlantic rains of the Storm cycle.
7. Capt. Jas. W. Harrel, in Imperial Blue-book Bechuanaland, London, 1883, says, "1880—Heavy rains on Molapo River such as have not been experienced for many years.	This is the regular cyclical mitigation rain that appears on all the cyclical diagrams except Cape Town where it was anticipated by the more powerful (locally) Storm cycle.
8. South African Quarterly Journal. Dr. Campbell had abundant rains in Winter 1820, in Bechuanaland.	Mr. Gamble places a mark of exclamation against this. The observation seems doubtful, and does not accord with Rob. Moffat's account of the climate of Bechuanaland.

9. Colonial Magazine, page 244—Protracted drought in Eastern Province in 1842, many farmers obliged to quit their farms by the entire failure of water. Both the Fish and Sunday's Rivers ceased to flow.

At page 362,—Abundance of rain in Kafirland in March and April 1843; Storm in Algoa Bay, 29th August, 1843.

Here we have the Storm cycle tempests due 1840·5, interfering with the lag rain due 1840·4, and the result seems to be a more or less complete deferring of the lag rain to the next cyclical period (end of 1842 or early in 1843) of the secondary Indian Ocean Cycle. It seems certain that this drought is the same as the drought and and rains of 1841—42 in Messrs. Brownlee, Birt and Thomson's list.

10. Royal Geo. Society Journal 1834.—Drought in September 1834 prevented Dr. Andrew Smith from getting to Latakoo (Kuruman).

The Sunspot Min. was in 1833, so that whatever the the nature of this drought, it occurred at the exact cyclical period. But the drought seems to have been severe from the following remark—"The climate of Bechuanaland must have undergone great change; within the memory of persons yet living sea-cows inhabited the Kuruman River where it is now without a drop of water." If Dr. Andrew Smith had visited the Kuruman River six years later during the lag rains of the Sunspot Max., he might have found sea-cows back in their old haunts!

11. Royal Geo. Soc., 1878—A. C. Bailie—"Very dry season 1876 in Bechanaland.

The regular drought of the Sunspot Min. It may be added that this was the year of the Madras famine, there being a prolonged sunspot minimum lasting from 1875 to 1879.

12. Royal Geo. Soc. Proceedings, vol. v., page 16—Jas. Chapman in letter to Sir G. Grey, writing in January 1860, from Otjimbinque, says, "We have had an unusually dry season; in the whole country up to the lake the fountains have failed, and if the dessication continues a few years longer at the rate it has done during the last four years, I fear we shall only be able to reach Ngami in the rainy season." "Lake Ngami has been very full for the last couple of years, and the Botletle River has filled up the great salt lake (which I discovered in 1854) with fresh water from Ngami.

Here we have the history of a drought of the Sunspot Min period in south tropical Africa. Salt Lake dry in 1854. Extreme min. period 1855·5; 1860, Max. Sunspot period, and end of drought very near, whole country dried up but lake Ngami filled with water coming from the country nearer the Equator, where the drought is already broken.

Compare this with present year 1888; next year 1889 is the extreme Sunspot Min. A low Nile is reported from Egypt and partial famine from South India, showing that the drought of the Sunspot Min. has already begun in equatorial regions.

13. Sparrman, And., M.D.,—Voyage to Cape of Good Hope ". . . . drought in 1775; Driest year in memory of man."

The regular drought of the Sunspot Min. Extreme min. of cycle 1777·7.

14. Thunberg, Chas. Peter—Travels in Europe, Africa, and Asia, 1770—1779. Drought in 1777—1778.

The same drought mentioned above by Sparrman, the regular drought of the Sunspot Min.

15. Earliest Met. Records, published by Cape Government from 1818 to 1825 speak of a very severe dronght 1821—23.

The regular drought of the Sunspot Min. Extreme min. of cycle 1822·2. For further particulars of this drought see referrence No. 5.

It need scarcely be added that this list of 15 meteological references is not selected from Mr. Gamble's catalogue. I have been at pains to extract from the catalogue every reference to remarkable seasons to which a date was attached. This catalogue was published in 1885, but I had no suspicion, until a recent visit to Cape

Town gave me an opportunity of seeing the catalogue, that the evidence of cyclical variation from remarkable seasons could have accumulated to its present strength.

The three most striking references in this list are the 5th, and the 13th and 14th, the two latter relating to the same drought. In the 5th reference we have, in 1822, rain in the west and drought in the east, the characteristics of the Storm cycle of our day. And we see the Storm cycle carried back unmistakably to A.D., 1822. In the 13th and 14th references we have the accounts of the drought in 1775—1777 by the travellers Sparrman and Thunberg carrying back the regular drought of the Sunspot min. for above a century.

CYCLICAL VARIATION IN KALIHARI DESERT.

The periodicity of the rainfall in the Kalihari desert was thus stated in my King Williams Town Lecture :—Livingstone in his travels, and other persons who have visited the Kalihari desert, bear testimony to the periodicity of good and bad seasons in that thirsty land. Rain is indeed so rare there that good seasons can be remembered with great precision. The information that I have gathered of rain in the Kalihari desert shows that the good seasons follow with surprising regularity on the years of sunspot maxima. Thus there were copious rains in the Kalihari in 1885—lag rain of sunspot max. Of 1874 the previous lag rain I have no informotion. But there were good rains in 1862 or 1863 which is the preceding period for lag rains. Going one cycle further back we find Livingstone speaking of the good rain in 1852. The rainfall generally he describes thus :—" In years when more than the usual quantity of rain falls, vast tracks of the country are literally covered with these melons *It happens commonly once every ten or eleven years* " : as we have seen, with the lag rains of the Eastern rainfall. In the Sahara desert, on the other side of our continent, there is a similar evidence of travellers, that the scanty rainfall occurs at intervals of ten or seven years.

PRICES OF FOOD GRAINS.

We have seen what strong evidence comes from India of the connection between the Sunspot cycle and the average price of food grains. In Cape Colony agricultural statistics are woefully deficient. I have ransacked all the Blue books available with the result, as might be expected, that maize and wheat are dearer in S. Africa during years of minimum than in years of maximum sunspots.

The opening of the Diamond mines in 1870 caused such an abnormal rise in the price of food grains and of everything else throughout the Colony that it would be useless, in this connection, to examine the price of food grains at that time. For 1873, complete statistics are wanting. In 1872 there was a year of maximum sunspots and of max. rainfall in the west ; and in 1874 came the lag rains to the centre and east of S. Africa. These rains occurred at the close of 1874, so it would be 1876 before prices throughout the Colony would be at their minimum. Taking the max. years of 1874-75-76 and 1884 and 1885, I find that the average price of maize throughout the Colony was, from the Blue-book returns, 7s. 1½d. per muid. For the years of minimum sunspots, 1877 to 1883, I find the average price of maize was 9s. 8d. Going through the same calculation for wheat I find that the average price has been 9s. 8½d. per muid for max. sunspot years and 10s. 11½d. per muid for minimum sunspot years. Eastern and western prices cannot well be separated, in an enquiry of this sort: the figures are less conclusive in consequence Thus, the average prices for 1874 and 1875, max. sunspot years, are raised by the drought that always precedes the lag rains in the east of the colony. The different secondary cycles in the Atlantic and Indian Ocean rainfalls are here neglected.

The following table, compiled from the Blue-Book returns, shows the average prices of wheat and maize (mealies) throughout Cape Colony, when prices were steady, after the diamond, and before the gold discoveries.

		Average price of Wheat per Muid throughout the Colony.	Average price of Mealies per Muid throughout the Colony.
1872	... ...	(£0 8 2½	£0 6 6)
1873	Maximum years.	... ...	... ...
1874		0 12 0	0 9 1¾
1875		0 11 7	0 8 0
1876		0 8 6	0 6 0
1877	Minimum years	0 12 3	0 10 3
1878		0 13 2	0 11 6
1879		0 9 8	0 9 0
1880		0 9 9	0 10 8
1881		0 10 9	0 8 11
1882		0 10 9½	0 9 8
1883		0 10 3¾	0 7 8½
1884	Maximum years	0 8 6	0 6 2
1885		0 8 0	0 6 4
	Average max. years	0 9 8½	0 7 1½
	„ min. „	0 10 11½	0 9 8

SUNSPOTS AND CUSTOMS RECEIPTS.

In the Cape of Good Hope Directory, the receipts from Customs are given from the year 1850. The Customs receipts, as an index of general prosperity, might be expected to show some correspondence, through the rainfall, with sunspots. I have tabulated the customs returns from the year 1850; arranging them according to the sunspot cycle, in three groups of maximum years, of intermediate years, and of minimum years. But it is difficult to draw any conclusion from the figures. In 1872 after the discovery of diamonds the customs revenue rose with a bound very nearly 100 per cent. If the figures are grouped into harmonious cycles only two eleven year cycles remain, and these exhibit irregular fluctuations not dependent on rainfall. Lastly there is the confusion resulting from the unavoidable mixing up of Atlantic and Indian Ocean rainfalls. It is not surprising therefore, that this line of enquiry gave negative results

RETARDATION OF RAINFALL.

We have seen, that at Madras, famines correspond with the downward bend of the sunspot curve; and usually make themselves felt before the lowest point of that curve is reached. Farther from the equator, there is a retardation or lagging of sunspot influence, in the case of food grain prices at stations north of Madras; this retardation increasing as the stations become more distant from the Equator. We have noticed cases where the maximum temperature has lagged four years behind the maximum of the sunspot cycle. Lastly, we have seen that in South Africa for all Eastern, Central, and Karoo Stations, *i.e.*, for about 9-10ths of the whole rainfall, the lag rain of the sunspot maximum is the only certain period for good seasons. For the last 33 years the heavy rainfall breaking up the droughts in the East of Cape Colony has come at exact intervals of 11 years; two years after the maximum of the Wolfian cycle, and two or three years after the observed maximum sunspot period. So that we have to look for a reason why, when we have the sun at its maximum power, drawing extra water from the ocean, it is two years, on an average, before we get the rainfall at the majority of South African stations. Thus, retardation is a most important feature in the rainfall of South Africa; and this lecture would not be complete without some attempt to account for it. As a working hypothesis we may consider retardation to be due to the difference between moisture in the air and the precipitation of that moisture. Everyone knows that moisture in the air and rainfall are by no means the same. The air is moister at East London than at King William's Town, but the rainfall is the same at both places. At Dordrecht, where the air is intensely dry, the mean rainfall is practically the same as at King William's Town and at East London. The mean rainfall at Mossel Bay more than half surrounded by the sea is 16 inches. At inland George, where the elevation of 600 feet and the mountains and forests, combine to cause precipitation of moisture, the mean rainfall is 31 inches. Erksine, quoted by Gamble, describes the country between Sofala and Delagoa Bay as almost rainless, clouds floating on unbroken to the hills. The exceptional oppressiveness of the air in the Red Sea is due to the moisture it contains, and there it scarcely ever rains. During the S.W. Monsoon in India, the rainfall at sea is but a fraction of that on the shore. The most striking instance of moisture in the air and no rain is the Peruvian climate. It never rains there; but, for the first half of the day, during the greater part of the year, the aid is so loaded with moisture, that the whole atmosphere is filled with a peculiar haze, termed the Gara. Through this haze the sun shines (as I have sometimes noticed it on the Amatola mountains), with the dull appearance of the moon. We are justified in assuming that the moisture in the upper atmosphere may be at its max. when the sunspots are at their maximum: while, for reasons which we shall now review, the heaviest rain may not come for two years afterwards.

It has been truly remarked that rain breeds rain, exactly as rain produces forests, and forests increase the rainfall. It is a common observation during droughts in South Africa, and the same thing has been remarked in Southern India, that the rain clouds pass over the heated earth in dense masses but refuse to break. In these latitudes, the sun, though partially obscured by the clouds, is sufficiently powerful to strongly heat by day the parched earth; inducing a current of warm dry air of which the action is to raise and disperse the clouds. By night the "drought" clouds hang over the earth and actually check that radiation and cooling of the earth which would otherwise tend to draw down and break the clouds. This state of things will last till a series of storms cools the heated earth and and clears the moist atmosphere. So far we seem on tolerably firm ground, but now to account for the breaking of the drought clouds, we may assume:—

(*a*). A gradual spreading of rain storms (and perhaps to some extent rain clouds) from the Equator, polewards.

(*b*). A series of atmospheric movements advancing (as our barometric depressions, and anti-cyclones travel) from West to East.

(*c*). The decline in solar energy, and consequently of radiant heat, after the sunspot max, In favour of (*a*) there are the facts: first, that as far as we can trace the incidence, or breaking up of single droughts the succession is from the Equator polewards; secondly, the mean lag or retardation of various droughts at different places increases with the latitude. This has been noticed in the course of this lecture.

In favour of (*b.*) it may be remarked thrt our rain-bringing storms invariably, in Cape Colony, come from the West. My own observations and that of weather observers in almost every part of the Colony abundantly confirms this. Then there are Dr. Meldrum's charts of weather over the ocean to the south and east of Cape Colony, exhibiting a steady movement eastward of bòth cyclones and anti-cyclones.

On this hypothesis we should assume that our upper atmoshere becomes moister shortly after the increased solar energy of the max. spot period produces increased evaporation; but that before this moisture can be precipitated as rain, we have to await a series of storms gradually advancing from the westward across the parched continent It must be confessed that we have no evidence of these gradually advancing storms; but, on the contrary, as soon as we get into the regular Karoo rain-fall we have the full two years retardation of the Eastern rainfall, vide cyclical diagrams for Graaff-Reinet and other Karoo stations; and compare these with the cyclical diagrams for Maritzburg Gardens-Cliffe, and Grahamstown. It will be seen that a three years' retardation is by no means so rare with a Karoo as with an Eastern rainfall. On the whole, the most satisfactory explanation of the retarded precipitation of Eastern rainfalls seems to be (*c.*) namely the simple decline of solar energy breaking the drought clouds by a lowered temperature. The cycle of temperatures at the Royal Observatory discussed at page 74, gave the following results for one 11 year cycle:—The temperature did not vary inversely as the local rainfall, but was high at the max. of sunspots, higher shortly before the drought clouds broke up into the lag rains, and highest during the min. sunspot year (1877), when there was local rain at Cape Town, but drought generally in South

Africa. Of course these temperatures are the combined effect of solar heating, and cloud and vapour screening, at the earth's surface ; and we can not separate the one from the other effect.

Whatever causes the breaking of the south-east clouds, it is always a startling phenomenon, somewhat analogous to the breaking of an Indian monsoon. It does not rain but it pours. Slight barometric depressions which had no significance before the drought, now bring down the rain in torrents; aud the face of nature changes, as it has changed during the last three years in the east of the Colony.

That " retardation " is a phenomenon of delayed precipitation seems to be proved from the following considerations. At Cape Town, the rainfall of the sunspot max. is punctual to within a few months, and the great lag rains of the rest of South Africa are entirely absent. Storms and evaporated moisture, here come together from the west, off the Atlantic. Looking at the diagram for Durban on the eastern side of the continent, it will be observed that, both the punctual and the lag rains, of the sunspot max. are represented. The rainfall returns for Port Elizabeth, for East London, and for coast stations generally show both periods represented. Consulting the diagrams for stations, a short distance from the coast, it will be seen that while the lag rain is the great rain period, rain at the exact sunspot max. is absent or very uncertain, vide cyclical diagrams for King William's Town, Grahamstown, and Maritzburg. There is even one seemingly lag rain at the inland western station of Ceres, which further meteorological observaiions will confirm or disprove. Glancing at the Karoo diagrams, it will be observed that the punctual rainfall of the sunspot max. disappears altogether. This leads to the important conclusion,that the *punctual rainfall of the sunspot max. is the precipitation along the coast line of local evaporation from the ocean ;* while the *lag rain of the sunspot max. is the breaking up* either by a lowered temperature or by storms, *of the great procession of clouds brought by the South-east Trade wind.* In discussing, the breaking up of the last drought in Kaffraria with the lag rains, it was noticed that the drought first broke at stations northwards and towards the Indian Ocean, then at stations (such as along mountain ranges) where from local causes, precipitation would be hastened; and then finally, on the plain between the mountains and the sea, represented by the station of King William's Town. Vide also, cyclical diagram for Aliwal (4,400 ft. elevation) showing early sunspot max. rains and late lag rains—page 102.

DROUGHT AHEAD.

At the present moment (* December, 1887), when the country around is waving with a superabundance of green grass; when the farmers are reaping bumper crops; we are rapidly nearing a period of minimum sunspots. It is exactly 11 years ago since the awful famine of 1876 desolated S. India, and the people sank dead, not by thousands or tens of thousands but by millions. Of course, they were Asiatics; their ways are not our ways; and it has been customary for them to perish in this way from time immemorial. But, I think it will bring home to you the force of the climatic change, when I mention that while the famine lasted, the number of deaths per month was about equal to the whole European population of Cape Colony!

We are now experiencing the third good season. The most cursory examination of the cyclical diagrams shows that few places can expect more good seasons. For most stations early droughts are indicated. As the drought period of the sunspot cycle approaches, we shall get the following signs of impending drought:—

(*a*). † Reports of famine in S. India, or the failure of the rains in tropical Africa, or elsewhere in the tropics.

(*b*) Scientific observations (a), on the appearance of the sun; (b) on the magnitude of magnetic perturbations.

Mr. Chambers, the Government Astronomer at Bombay, tells us, as has been mentioned, that the magnetic phenomena precede the sunspot appearances, by about six months; so that the magnetic observations as indications of solar energy have a prior value to that extent. Happily the Wolfian Cycle is a better indicator of solar energy, as this affects our climate, than either the less regular sunspot or magnetic observations. The Wolfian Cycle is now nearing its minimum in 1888·8 = the year ending November 17th, 1889. In other words, the sun is weaker than it was six years ago. It is drawing up less moisture from the ocean, less from the forests and moist places on the earth. In two or three years the grass may be less green than it is now! I hope that we shall get over the minimum period without any serious drought, that the mitigation rains may so mask the regular drought of the sunspot minimum that the cycle of drought may slip past without your noticing its deadly grasp. As the critical time approaches, every prudent man will be on his guard. Should the drought prove severe, he will not imagine that there is a curse on the land; but, reflecting on the drought as in the natural course of events, he will look forward with the greater confidence to the breaking of the drought, which will happen thus:—

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* The date of delivery of this lecture.

† Since this lecture was delivered reports have appeared in the newspapers of a famine (happily not a severe one) in Southern India, and of very low water in the Nile, indicating drought in tropical Africa.

	PROBABLE.	CERTAIN.
West; and S.W. Coast	One year light rain, 1892.	One or two years good rain max. in 1894.
East; & South Africa generally.	One year good rain 1892.	Two or three years good rains beginning about 1896.

Vide pages 83 and 109.

The moral of all this is, that the sunspot cycle should take its place as a hard fact in every farmer's head; the rainfall probability deduced from the cyclical diagram of the locality should be shown in every colonial almanac.

In the future, the cyclical forecast may not always turn out correct, exactly as the fickle elements give us warm winters and cold summers. But, behind these vicissitudes, is the law of cyclical variation, which must prevail in the future, as we have seen it has prevailed, in the past.

THE END.

APPENDIX.

Schwabe's letter giving his sunspot work to the Royal Astronomical Society of England.

Gentlemen,—The request contained in your letter, although in the highest degree honourable and complimentary to me, and although it gave me an opportunity to show the Royal Astronomical Society my gratitude for the Royal Medal granted to me, has still cost me some struggle before complying with it; for it is not easy to part with what has given me very often much pleasure and enjoyment, as a compensation for the labour devoted to the work. But in complying with your desire, I do so on one condition, viz., that you would grant me permission to obtain the observations back again, at any time, that I should be desirous of looking into them, during the short time of life still left to me. I do not think that I should have an occasion to avail myself of the permission asked for, but permit me kindly to believe that it is in my power to do so. After my death you may consider the whole of the observations as the property of the Royal Astronomical Society.

Please to write to me if you are willing to agree to the above desire, and I shall then immediately send you my astronomical diaries, &c., from 1825 to the end of 1864.

I remain, Gentlemen,
Yours very faithfully,

S. H. Schwabe.

On receipt of this letter, Mr. Loewy was despatched to Dessau by the Director of the Kew Observatory, and Hofrath Schwabe delivered into his hands 39 volumes, which have remained at Kew till the present time, but which are held by the Observatory as the property of the Royal Astronomical Society.